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THESIS

MAINTENANCE ERROR INFORMATION SYSTEM (MEIMS) UPGRADE AND TRAINING EVALUATION

by

Michael E. McCracken

December 2000

Thesis Advisor:	John K. Schmidt
Associate Advisor:	Douglas Brinkley

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The purpose of this thesis is to study the usability an upgraded Maintenance Error Information Management System (MEIMS) tool used to capture human error in Naval Aviation maintenance mishaps. Built upon the Human Factors Analysis and Classification System-Maintenance Extension taxonomy, the tool provides the framework for examining maintenance errors that lead to mishaps, incidents, and personal injuries. The tool is developed for safety personnel, mishap investigators, Aircraft Mishap Board members, and analysts. In limited usability testing, the tool was found to be useful, but in need of revisions, specifically regarding functionality and user friendliness. Additionally, a tutorial is provided to better prepare targeted users of the tool. The study requires a review of mishap information systems, human error theories related to aviation mishaps, design considerations for human-computer interfaces and usability study applications. A follow-on usability study, conducted using two groups of potential users, one which received the tutorial and one which did not. It includes a survey regarding subjective responses about the prototype tool. The results indicate that the tutorial is effective in preparing and assisting potential users, and that the tool could make a significant impact in the reduction of mishap rates due to maintenance error.

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MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) UPGRADE AND TRAINING EVALUATION

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Lieutenant Commander, United States Navy
B.S., United States Naval Academy, 1984

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE IN INFORMATION TECHNOLOGY MANAGEMENT

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ABSTRACT

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LIST OF ACRONYMS

AGM	Aircraft-Ground Mishap
AMB	Aircraft Mishap Board
ASO	Aviation Safety Officer
CSA	Command Safety Assessment
DOD	Department of Defense
DON	Department of the Navy
EXP	Experience
FAA	Federal Aviation Administration
FM	Flight Mishap
FRM	Flight-Related Mishap
FY	Fiscal Year
GUI	Graphical User Interface
HCI	Human-Computer Interface
HFACS	Human Factors Analysis and Classification System
HFACS-ME	HFACS –Maintenance Extension
HFQMB	Human Factors Quality Management Board
MDA	Maintenance Mishap Data Analysis
MEDA	Maintenance Error Decision Aid
MEIMS	Maintenance Extension Information Management System
MRM	Maintenance-Related Mishap
MX	Maintenance
NSC	Naval Safety Center
NPS	Naval Postgraduate School
NTSB	National Transportation Safety Board
OB	Organizational Benchmarking
ORM	Organizational Risk Management
RAM	Random Access Memory
RNG	Range
SD	Standard Deviation
SHEL	Software, Hardware, Environment, and Liveware (Edwards' Model)
SIMS	Safety Information Management System (Naval Safety Center)
SQDRN	Squadron
TACAIR	Tactical Aircraft
TEAM	Tools for Error Analysis in Maintenance (Galaxy)
USN	United States Navy
YRS	Years

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DEDICATION

This study is dedicated to my family. Love and gratitude is expressed to my parents, James and Maureen McCracken. Thank you for setting the best example of parenting that I know of. Throughout my life, you have provided me the foundation to accept and overcome any challenge I have had to face. Your unconditional love and understanding have been both a comfort and a support upon which I have continually relied.

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I. INTRODUCTION

A. OVERVIEW

1. Background

In the last half century, Naval Aviation has reduced the Class A Flight Mishaps (FM) rate significantly. In fact, the Class A FM rate was reduced by 50 percent in each decade from 1950 to 2000 (see Figure 1). Despite this success, the cost of mishaps, in terms of lives and assets, remains too high. Furthermore, human error, attributable to four out of every five mishaps, has remained constant (Nutwell & Sherman, 1997). In response to a 1996 F-14 Tomcat FM, which was largely attributable to human error, a Human Factors Quality Management Board (HFQMB) was initiated to study human error in Naval Aviation mishaps. The HFQMB's charter (1997) was to reduce the mishap rate by identifying systematic improvements in processes and systems that affect human performance and to institutionalize continual improvements in these areas. The HFQMB is made up of Flag Officers, senior operational officers, and a cross section of Commanding Officers to seasoned naval aviators from all communities. Their objective was to reduce the Class A FM rate by half within three years, and by 75 percent within 10 years (HFQMB, 1997).

The HFQMB's strategy entailed a three-pronged approach: (1) Mishap Data Analysis (MDA), (2) Organizational Benchmarking (OB), and (3) Command Safety Assessment (CSA). MDA studies historical records to determine established trends of human error in aviation mishaps. The Human Factors Analysis and Classification System (HFACS) was developed to accomplish this task. By examining and classifying past mishaps, prevailing human errors are prioritized and targeted for prevention. The second phase, OB, involved the observance of other organizations, both military and civilian, for procedures and practices that might be useful in helping reduce the occurrence of human error. To this end, Naval Aviation adopted Organizational Risk Management, which associates conditions with risk and decision making methodology to reduce the occurrence of aviation mishaps, directly from the U. S. Army (Department of the Navy, 1997). CSA was developed at the Naval Postgraduate School by Civarelli and Figlock (1997) as a tool to measure the safety climate in a squadron from an aircrew perspective. It solicits opinions and attitudes towards procedures and practices to determine the effect of organizational and supervisory issues on flight safety (Nutwell & Sherman, 1997).

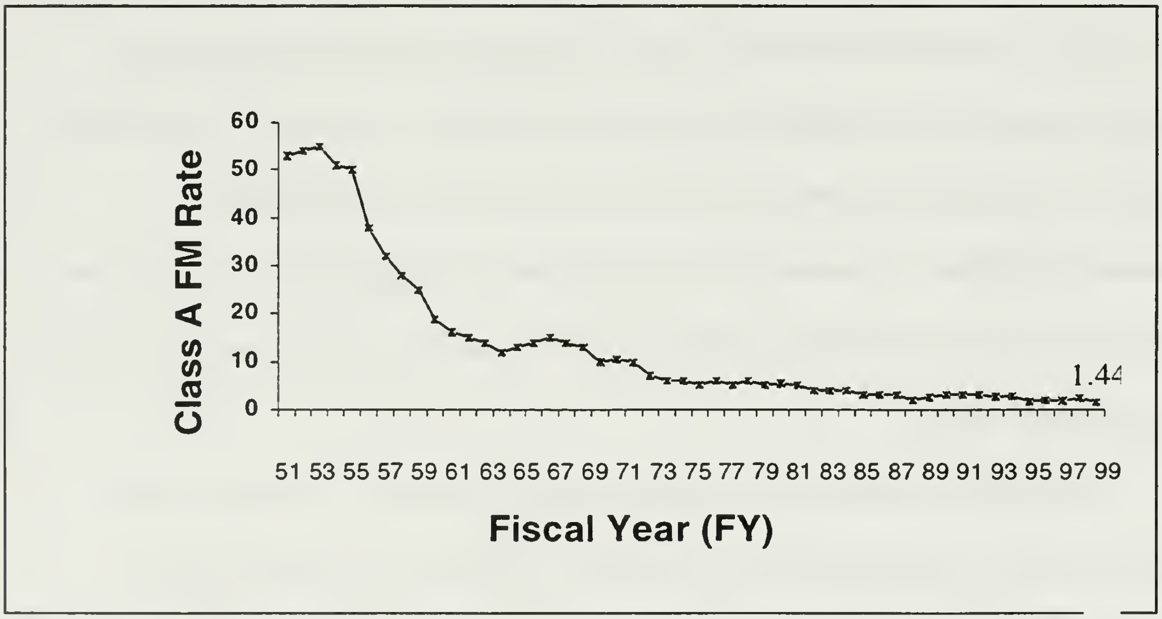

Figure 1: FY 1950-1999 Naval Aviation Class A Flight Mishap Rates (From School of Aviation Safety, 1999)

In January 1999, the Vice Chief of Naval Operations extended the short-term goal of 50 percent reduction in Class A FM mishap rate from the end of FY1999 to the end of FY2000. To meet this goal, the scope of the HFQMB needed to expand to include human error in maintenance mishaps. Historically, approximately one in every five Class A FMs contains maintenance error. By expanding the focus to include maintenance error, it was believed that the 50 percent reduction objective could be met. An identical three-prong approach that had been used for aircrew error was utilized for maintenance error.

2. Maintenance Mishap Data Analysis

HFACS was developed as a framework for examining aircrew and supervisory error in Class A FMs. It concurs with the Naval Aviation Safety Program's (OPNVAVINST 3750.6) notion of multiple causal factors, chain of events, and human factors. A maintenance extension (ME) was added to HFACS to meet the HFQMB's expanded scope and was used to examine incidents and injuries (Schmidt, Figlock & Teeters, 1999), and major to minor mishap data (Schmidt, Schmorrow & Figlock, 2000). HFACS-ME was adopted for the upcoming revision of the Naval Aviation Safety Program. Furthermore, a laptop prototype tool, Maintenance Extension Information Management System (MEIMS) was developed to allow users to collect, catalog, collate and analyze mishap data, to better identify trends and for safety training. MEIMS, in limited usability testing, was determined to be a valuable tool that will provide the fleet great benefit (Wood, 2000).

B. PROBLEM STATEMENT

To meet the objective of a 50 percent reduction in Class A FMs, both aircrew and maintenance error needed to be targeted. The HFACS-ME taxonomy and MEIMS were developed to better analyze maintenance error. While proven useful in a limited usability study, MEIMS is not without limitations. Users found the tool to be somewhat difficult to navigate, was lacking in assistance functionality and its interface needed to be more user-friendly. Additionally, it was determined that its intended users (e.g., squadron maintenance and safety personnel, squadron safety officers, Aircraft Mishap Board members, Naval Safety Center analysts, etc) would benefit from a training tutorial prior to accessing the tool (Wood, 2000). This study will further develop MEIMS based upon the initial usability study. It is believed that the fleet user, with proper training, should be able to easily access the tool and obtain useful information, which can then be used in training, hazard identification and trend analysis, to prevent future mishaps.

This thesis investigates the following questions:

1. What query capabilities are required by the users of the information system to best identify problem areas and trends?
2. What additions will make the information system more user-friendly, allowing efficient and effective access to the system's capabilities?
3. What kind of training, in the form of a tutorial, would best prepare users to efficiently and effectively access the information system's full capabilities?

C. PURPOSE

The intent of this study is to refine and evaluate the existing safety information management system, which uses the HFACS-ME taxonomy as its basis, to better facilitate data collection, organization, query, analysis and reporting of maintenance personnel errors that contribute to Naval Aviation mishaps, equipment damage and personnel injury. Included are theoretical approaches that examine mishaps involving human error: Heinrich's "Domino" Theory, Edwards' "SHEL" Model, and Reason's "Swiss Cheese" Model. These models not only help identify the unsafe actions which cause mishaps, but they also connect the conditions underlying the mishap. HFACS-ME is a composite derivative of these taxonomies. Although there is no universally accepted method of accident investigation (Benner, 1975), some standardized aircraft accident investigation procedures have been adopted by most agencies throughout the world (Diehl, 1991). Using HFACS-ME as its basis, MEIMS will significantly improve access and analysis of mishap data.

The results of this study will (1) improve and enhance the MEIMS prototype tool's usability so that data can be easily queried and analyzed, (2) creation of a tutorial for fleet customers that will enhance their ability to not only access the data base, but to efficiently and effectively use this information to prevent future mishaps, and (3) study the performance of two groups of participants, with only one group receiving the tutorial, to determine the effectiveness of the tutorial for fleet users.

D. SCOPE AND LIMITATIONS

MEIMS will be revised to include a users' tutorial. Fleet personnel, primarily Aviation Safety Officers, will test MEIMS to determine its usability and the benefits of the help and tutorial functionality. The fully developed MEIMS tool will be used primarily by Naval Aviation squadrons, but may have some crossover use by other military branches and civilian airlines. Only maintenance related mishaps caused by human error are considered. No material failure factors or maintenance related hazard reports or personnel injuries not related to a mishap are included.

E. DEFINITIONS

This study uses the following definitions:

Aircraft Mishap Board: Group of officers appointed to investigate and report on an aviation mishap.

Aviation mishap rate: Number of aviation mishaps per 100,000 flight hours.

Aviation Safety Officer: Principal advisor to Naval Aviation squadron commanding officers on all aviation safety matters.

F-14 Tomcat: U. S. Navy's swing-wing, supersonic fighter aircraft with air-to-air, air-to-ground, and reconnaissance capability.

Fleet Logistics Support Wing: U. S. Navy reserve air wing comprised of transport aircraft.

HFACS: Human Factors Analysis and Classification System designed to help analyze Naval Aviation mishaps focusing on aircrew error.

HFACS-ME: Human Factors Analysis and Classification System--Maintenance Extension adaptation to classify causal factors that contribute to maintenance mishaps.

HFQMB: Human Factors Quality Management Board established by Naval Aviation senior leadership to reduce human error involvement in Naval Aviation Class A flight mishaps.

MEIMS: Maintenance Error Information Management System, a prototype tool developed to collect, catalog, collate and analyze mishap data.

Mishap: A naval mishap is an unplanned event or series of events directly involving naval aircraft, which result in $10,000 or greater cumulative damage to naval aircraft, other aircraft, property, or personnel injury.

Mishap Categories: Naval aircraft mishap categories are defined below:

Flight Mishap (FM): Those mishaps in which there was $10,000 or greater DOD aircraft damage or loss of a DOD aircraft, and intent for flight for DOD aircraft existed at the time of the mishap. Other property damage, injury, or death may or may not have occurred.

Flight Related Mishap (FRM): Those mishaps in which there was less than $10,000 DOD aircraft damage, and intent for flight (for DOD aircraft) existed at the time of the mishap, and $10,000 or more total damage or a defined injury or death occurred.

Aircraft Ground Mishap (AGM): Those mishaps in which no intent for flight existed at the time of the mishap and DOD aircraft loss, or $10,000 or more aircraft damage, and/or property damage, or a defined injury or death occurred.

Mishap Severity Class: Mishap severity based on injury and property damage.

Class A: A mishap in which the total cost of property damage (including all aircraft damage) is $1,000,000 or greater; or a naval aircraft is destroyed or missing; or any fatality or permanent total disability occurs with direct involvement of naval aircraft.

Class B: A mishap in which the total cost of property damage (including all aircraft damage) is $200,000 or more, but less than $1,000,000 and/or a permanent partial disability, and/or the hospitalization of five or more personnel.

Class C: A mishap in which the total cost of property damage (including all aircraft damage) is $10,000 or more but less then $200,000 and/or injury results in five or more lost workdays.

Naval Aircraft: Refers to U.S. Navy, Naval Reserve, and Marine Corps aircraft.

OPNAVINST 3750.6: The Naval Aviation Safety Program: U.S. Navy instruction outlining Naval Aviation's safety program.

ORM: Operational Risk Management. A decision making tool to increase effectiveness by anticipating and reducing hazards, thus increasing the probability of a successful mission.

F. ORGANIZATION OF STUDY

Chapter II contains a literature review on the development of a prototype to identify human error involvement and patterns in aviation maintenance mishaps. The methods used in this study are discussed in Chapter III. The results of this study are presented in Chapter IV. Finally, Chapter V contains conclusions, findings, and recommendations.

II. LITERATURE REVIEW

A. OVERVIEW

The literature studied encompasses human error, maintenance error in aviation, error classification and analysis. It includes textbooks, research articles, and masters thesis pertaining to: (1) human error theories, and their relation to maintenance related aviation mishaps, (2) accident information management, and (3) design and usability assessment of software tools. This information provides the basis for the continuing development of the maintenance error analysis and reporting prototype tool.

While ongoing efforts to reduce the number of Class A mishaps in Naval Aviation are to be applauded, there is potential for further improvement, especially in the area of human error. When examining mishaps involving human error there are numerous theoretical approaches from which to choose (Goetsch, 1996). Some are founded in industrial safety; others are viewed from a complex systems perspective, emphasizing human factors and operator error. Some approaches use models drawn from the domain of preventive medicine that employ epidemiological factors to analyze accidents, while other models utilize a combination of these approaches (Schmidt, 1998).

B. ACCIDENT DATA AND MANAGEMENT

1. Investigation and Reporting

Diehl's (1991) three-stage model of accident investigation and prevention focuses on human performance and systems safety considerations (see Figure 2). Diehl's stages are Accident Generation, Accident Investigation Process, and Preventive Measures. The purpose of the first stage, Accident Generation, is the identification of hazards. Hazards are circumstances or conditions which have the potential to lead to an incident (near-accident) or even an accident. The second stage, Accident Investigation Process, includes the collection, analysis, and review of accident data and the focus of this review. In aircraft accident investigations, procedure calls for a fact finding body to investigate the accident to determine *what happened*, and subsequently *what caused* accidents. Lastly, a final report is made, which details causes of accidents and makes recommendations to prevent reoccurrence (Diehl, 1991).

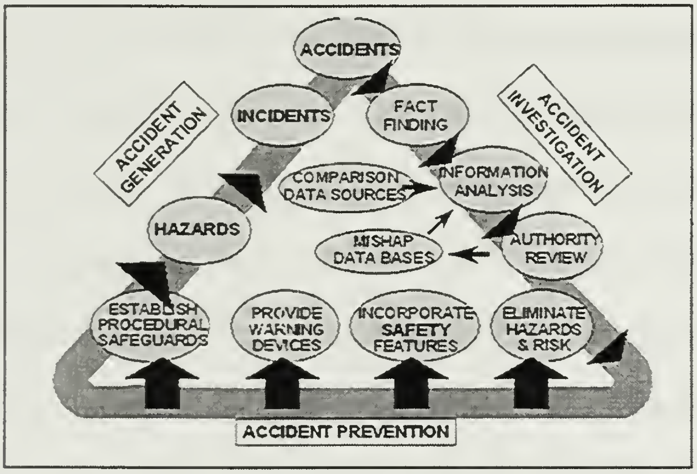

Figure 2: Accident Generation, Investigation, and Prevention Elements (After Diehl, 1989)

The final stage, Prevention Measures, details the methods used to avoid future accidents. There are four categories of accident-prevention measures: (1) eliminating hazards and risks, (2) incorporating safety features (3) providing warning devices, and (4) establishing procedural safeguards. In ascending order, these measures are more effective, but are also more expensive and more difficult to attain (Diehl, 1991).

2. Accident Prevention

In the early 1900s, accident investigations were based on the notion people commit unsafe acts that lead to incidents (Heinrich, 1959). This blame-based practice deterred systematic accident prevention until the 1950's, when systems engineering emerged from of the U.S. military's large-scale weapons program. Applied to accident prevention, systems engineering focuses on the strengths and limitations of components, including the human element, as an integral part of the system (Heinrich, Petersen & Roos, 1980). Presently, up to 90 percent of accidents can be attributable to human error in a variety of government, military and industrial settings (Heinrich, Petersen, & Roos, 1980; Hale & Glendon, 1987; School of Aviation Safety, 2000), so analyzing the human element can vastly improve the understanding of systems and why they fail.

Operational Risk Management (ORM), an outgrowth of systems engineering, is a tool that the armed forces employed to decrease accidents. ORM focuses on the identification of hazards during mission planning to effect control measures which reduce the associated risk. It is especially effective in highlighting human factor hazards (DON, 1997). The U.S. Army's aviation branch achieved record low accident rates in 1995 and 1996, largely attributable to their employment of ORM (DOA, 2000). Since 1997, the other military services institutionalized ORM into their operational doctrine (School of Avaition Safety, 2000).

3. Data Management

To be useful in the prevention of accidents, relevant data must be collected and properly archived for future reference. Coding the data and the use of data bases have become universally accepted methods for this task. The National Safety Council established a numerical code system relating to each cause factor (National Safety News, 1975). This method of coding simultaneously made referencing for specific cause factors much simpler, and also provided more efficient analysis capability by focusing on specific causes rather than accidents as a whole. Additionally, it is essential to also include "near-miss" incident data, as their circumstances are as likely to cause an accident in the future. Computer analysis tools can significantly aid reviews of mishap histories (Grimaldi & Simonds, 1984). To be truly effective in reducing future accidents and incidents those tools must organize and tabulate the data logically, and present it for analysis in easily accessible, user friendly formats.

C. ACCIDENT CAUSATION THEORIES

There are numerous theoretical approaches to examine mishaps involving human error (Goetsch, 1996). Three of the most recognized approaches are Heinrich's Domino Theory, Edwards' SHEL Model and Reason's Swiss Cheese Model. Despite differences in approach and originating source, these theories compliment each other and provide a solid foundation for analyzing human error in avaition mishaps.

1. Heinrich's "Domino" Theory

Considered to be the original accident theory (Goetsch, 1996), it details a linear five step sequence of related factors (chain of events) that lead to an actual mishap. Bird (1980) also held this view. The two central principles of the Domino Theory are (Bird, 1980): (1) accidents are caused by the combined actions of the preceding factors, and (2) removal of the middle factor (unsafe act or condition) will negate the actions of the preceding factors and thus prevent accidents and injuries (see Figure 3).

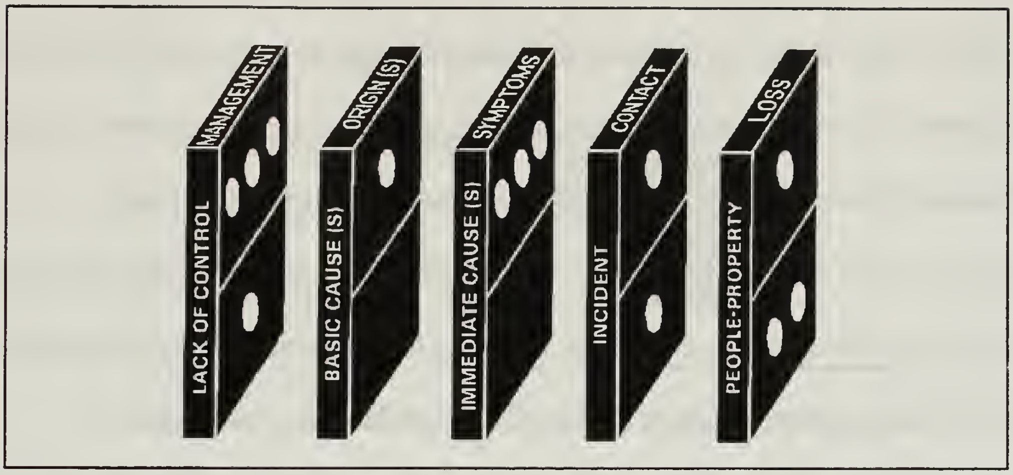

Figure 3: The Five-Step Domino Sequence (Bird, 1980)

Heinrich's original five-factor model (Heinrich, Petersen, & Roos, 1980), can be paraphrased as follows:

1. Lack of Control: This is a management issue where the emphasis is placed on the control exercised in a situation for an array of factors.
2. Basic Cause(s): This identifies the origin(s) of the causes and includes aspects such as human factors, environmental factors, or job-related factors.
3. Immediate Cause(s): This includes substandard practices and conditions that are symptoms of the basic causes.
4. Incident: This typically involves contact with the hazard, and for example, results in a fall or impact with moving objects.
5. Personal Injury and Property Damage: This includes lacerations, fractures, death, and material damage.

Each step preempts the next, causing it to occur; much the same way as one domino falling causes the next domino in sequence to fall as well. Removal of the factors that comprise any of the first three "dominos" will effectively intervene to prevent the accident.

2. Edwards' "SHEL" Model

The "SHEL Model" (see Figure 4) of system design was developed in the early 1970's to provide a better way to evaluate failures in human-machine systems (Hawkins, 1992). It identifies and defines four system dimensions: Software, Hardware, Environment, and Liveware. The "SHEL Model" provides a method to describe systems, identify potential areas for concern within a system, and proposes a general framework for accident investigation. Edwards (1988) defines SHEL concepts as follows: Software: the rules, regulations, laws, orders, standard operating procedures, customs, practices, and habits that govern the manner in which the system operates and in which the information within it is organized. Software is typically a collection of documents.

1. Hardware: the buildings, vehicles, equipment, and materials of which the system is comprised.
2. Environmental conditions: the physical, economic, political and social factors within which the software, hardware, and liveware operate.
3. Liveware: the human beings involved with the system.

According to the "SHEL Model," the system will fail when a disconnect occurs in any one of the four dimensions, or in the connections between them. People are rarely the sole cause of accidents (Edwards, 1988), but rather, accidents are caused by the interaction of several factors (Shappell & Wiegmann, 1997). This multi-factor theory was a significant departure from the commonly held belief that accidents were caused by single events.

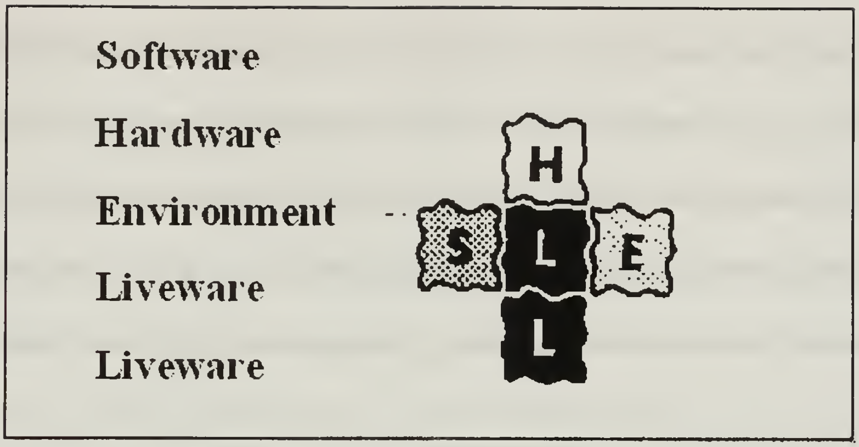

Figure 4: SHEL Model of System Design (Hawkins, 1993)

3. Reason's "Swiss Cheese" Model

Reason's "Swiss Cheese" Model employs a vertical association human factors approach to a collection of factors that eventually lead to an accident. It differentiates between two types of errors: 1) active failures, whose effects are felt immediately, and 2) latent conditions, whose effects may lie dormant until triggered later, usually by other mitigating factors (Reason, 1990). Latent conditions "set the stage" for an accident while active failures tend to be the catalyst for the accident to finally occur. The model can be thought of as slices of Swiss cheese lined up, with each vertical slice representing a defense layer (e.g. training, good management, teamwork, etc.) and each hole representing an active failure or latent condition in that defense (see Figure 5). Should a situation where holes line up come to pass, an accident will occur.

This is a dynamic model with each defensive layer coming in and out of prominence according to situational characteristics (Reason, 1990). An event may occur in one of three levels: (1) person-unsafe acts, (2) workplace-error provoking conditions, and (3) organization-error establishing conditions. Organizational factors, in which strategic decisions and associated processes (budgeting, forecasting, resource allocation) are initiated, provide the starting point for an accident (Reason, 1997). These processes, influenced by corporate culture, are distributed throughout the organization to individual workplaces. Corporate processes, evidenced as inadequate staffing, time pressures, equipment, training and working conditions, combine with the natural proclivity to commit errors and/or violations, to result in unsafe acts. Few of these acts, however, actually create holes in the defense layers en route to becoming an accident.

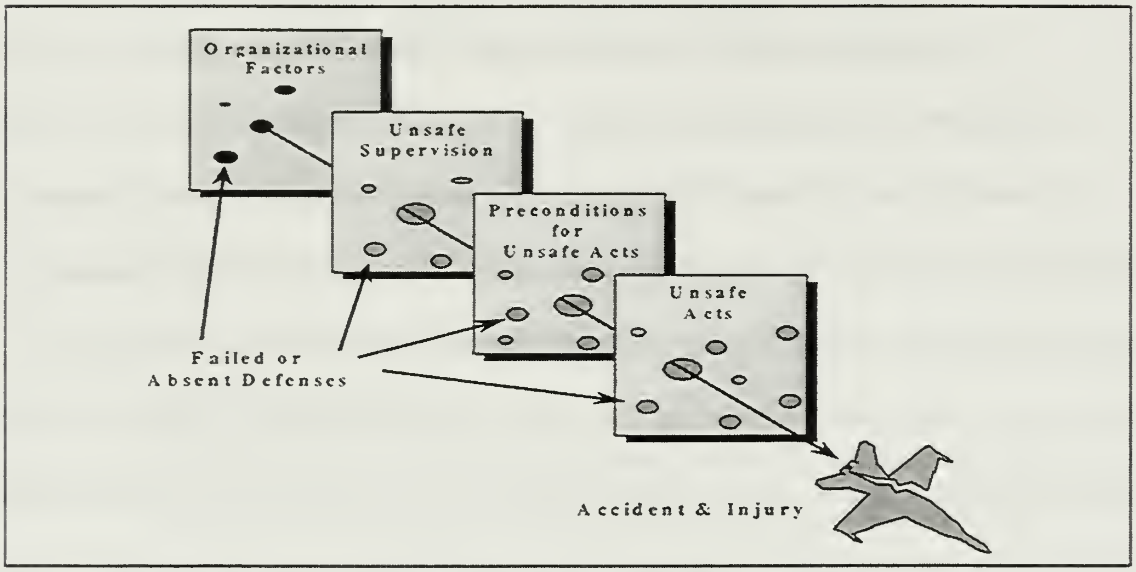

Figure 5: Reason's Swiss Cheese Model (Naval Safety Center, 1996)

D. HUMAN FACTORS ANALYSIS & CLASSIFICATION SYSTEM (HFACS)

Efforts to analyze aircrew error in Naval Aviation mishaps led to the development of HFACS (Shappell & Wiegmann, 1997). It began as a restructuring and expansion of the Swiss Cheese Model, but it also includes features of Heinrich's Domino Theory and Edwards' SHEL Model. The HFACS taxonomy recognizes the set of conditions within which system operators perform, accounts for interrelationships among conditions, and provides an overall sense of order or implied hierarchy. It identifies both active failures and latent conditions within four categories (DON, 2000): (1) unsafe acts; (2) preconditions for unsafe acts; (3) unsafe supervision, and (4) organizational influences. This classification is then used to target the most appropriate intervention.

While Reason's "Swiss Cheese" model is widely held as integral to explaining accidents, it does not provide a means of delineating precursors to accidents (Shappell &, Weigmann 1997). Although modern analysis systems are heading in the right direction regarding human factors investigation, more effort is needed. There exists a requirement for a framework that allows for the explanation of accident causation involving human error to include not only the causes of those errors, but also an explanation of those causes. It is through such efforts that further occurrences of the same type of accident can be avoided.

1. Maintenance Mishaps

The aviation industry has, in recent years, begun to apply human error theory to maintenance-related mishaps with the intent of modernizing accident investigations (Marx, 1998). Previously, it was believed that every error could be traced back to a basic set of actions and associated conditions that precipitated the error (Goetsch, 1996). This simplistic view did not allow for errors to have multiple causes, as most do. Additionally, traditional investigation techniques, while appropriate for identifying the causes of equipment failures, did not have the same success with human error-related accidents (O'Connor & Bacchi, 1997). Typically, investigations would effectively end when the cause pointed to human error, with no effort expended in attempting to explain why the error occurred.

In a review of investigation and analysis systems for aircraft maintenance error, the need for human factors investigation and reporting was identified (Marx, 1998).

Although human factors investigation methods are acknowledged as critical to understanding why people make certain mistakes, they have not been widely adopted. The proper investigation of human factors, however, is vital to accident prevention (Harle, 1994). The lack of thorough human factors investigation was caused by the tendency to place blame, inability to see through proximate causes to underlying causes, and an over-emphasis on static factors such as who, what and when (Marx, 1998).

2. HFACS-ME Maintenance Extension

In light of the above requirements, the HFACS taxonomy was adapted, and augmented to classify factors that lead to maintenance mishaps (Schmidt, 1996). The Maintenance Extension (ME) of the original HFACS taxonomy focuses on causation factors particular to the maintenance environment. These aspects and their relevant sub-section classifications are given in a manner similar to Reason's model. In the HFACS-ME model, a maintainer's performance is seen as being influenced by a series of latent conditions (supervisory, maintainer and working conditions) that can lead to an Unsafe Maintainer Act, which in turn can lead to a mishap, injury or an unsafe maintenance condition (see Figure 6).

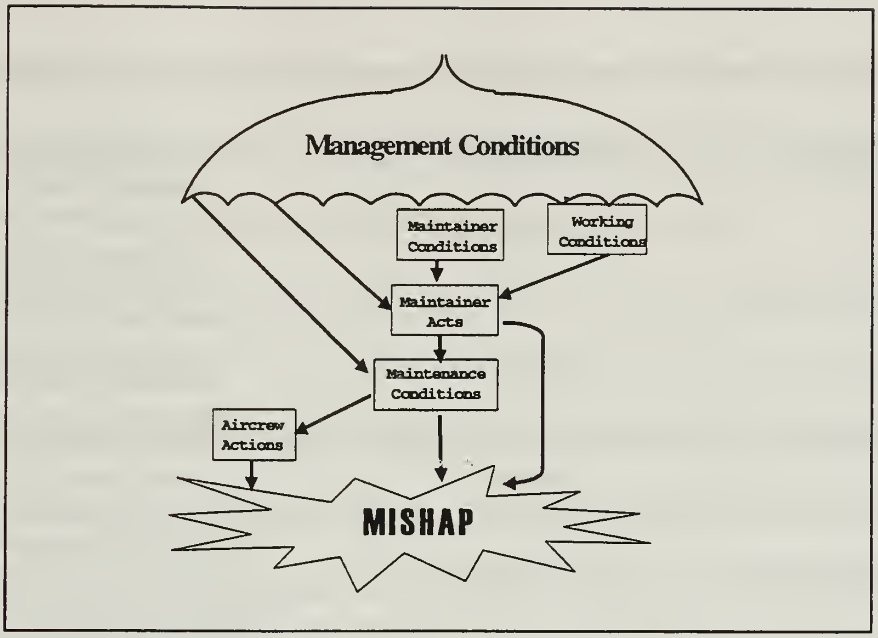

Figure 6: HFACS Maintenance Extension (HFACS-ME) (DON, 2000)

HFACS-ME consists of four broad human error categories, three latent: Management Conditions (e.g. inadequate supervision), Maintainer Conditions (e.g. preparation/training), Working Conditions (e.g. lighting/light), and the fourth Maintainer Acts (e.g. skill error), is active (DON, 2000). The three orders of maintenance error (first, second, and third) reflect a decomposition of the error types from a macro to a micro perspective. Each successive order provides for greater granularity, serving the respective purposes of identifying problem areas, prioritizing potential targets, and tailoring intervention strategies (see Table 1).

Table 1: HFACS Maintenance Extension Categories (DON, 2000)

First Order	Second Order	Third Order
Management Conditions	Organizational	Inadequate Processes Inadequate Documentation Inadequate Design Inadequate Resources
	Supervisory	Inadequate Supervision Inappropriate Operations Uncorrected Problem Supervisory Misconduct
Maintainer Conditions	Medical	Adverse Mental State Adverse Physical State Unsafe Limitation
	Crew Coordination	Inadequate Communication Inadequate Assertiveness Inadequate Adaptability/Flexibility
	Readiness	Inadequate Training/Preparation Inadequate Certification/Qualification Personnel Readiness Infringement
Working Conditions	Environment	Inadequate Lighting/Light Unsafe Weather/Exposure Unsafe Environmental Hazards
	Equipment	Damaged/Unserviced Unavailable/Inappropriate Dated/Uncertified
	Workspace	Confining Obstructed Inaccessible
Maintainer Acts	Error	Attention/Memory Knowledge/Rule Skill/Technique Judgment/Decision
	Violation	Routine Infraction Exceptional Flagrant

3. Maintenance Error Information Management System (MEIMS)

The HFACS-ME taxonomy was used as the framework for the development of a laptop prototype database tool, MEIMS. It is intended for fleet users to collect, catalog, collate and analyze mishap data, and to better identify trends and for safety training. In limited usability testing, MEIMS was proven to be effective, yet was lacking in some areas. Specifically MEIMS was somewhat difficult to navigate, was lacking in assistance functionality and it's customer interface needed to be more user-friendly. The benefit of user training was also indicated. To fully reach its potential, however, MEIMS needs design refinements and more rigorous usability testing (Wood, 2000).

E. USER INTERFACE

The proliferation of computer systems into ever increasing environments highlights the need for effective and easy to use interfaces. Clearly, the user interface is the most important factor in determining the success or failure of a software application (Liu, 1997). The design objectives of user interface include effectiveness, efficiency, comfort and safety. The content of an interface should abstract critical features of the target system (Norman, 1983; Vicente & Rasmussen, 1992), be consistent with human conceptual and cognitive characteristics (Carroll, Mack & Kellog, 1988; Wickens, 1992), be compatible with human response tendencies (Myers, 1991; Shneiderman, 1983), and should help users effectively achieve their intended impact on the target system (Sheridan, 1984; Shneiderman, 1992).

Williges, Williges & Elkerton (1987) examined design objectives from user's perspective and generated a list of seven general design principles as a basis for developing specific design objectives. The principles are (1) consistency, (2) compatibility, (3) memory, (4) structure, (5) feedback, (6) workload, and (7) individualization. According to these principles, a well designed user interface should maintain the same style of interaction within itself and similar applications (consistency), provide easily understandable interface symbols and icons to minimize the demand for information recoding (compatibility), minimize the demand on the user's short-term memory (memory), help users understand the structure of the system (structure), provide feedback and error-correction mechanisms (workload), and accommodate individual differences (individualization).

From an engineering point of view, Shneiderman (1992) detailed four essential classes of goals for interface design. They are (1) functionality to accomplish all assigned tasks, (2) foolproof reliability, availability, security and data integrity, (3) standardized styles and interface features to ensure portability over multiple applications, and (4) development should maintain schedule and remain within budget. The goal of interface design not only includes assisting the user in accomplishing their task of controlling or influencing a target system, it should also help the user understand the system.

In most cases, the target system and the user interface are usually designed by separate individuals, who are often from different groups or organizations. The design activities may take place at different places and at different times, making effective communications between the two groups especially challenging. The two design teams may have different objectives, constraints and conceptual bases. Interface designers must establish early contact with not only future users of the system, but also designers of the system so that both the "user model" and the "design model" can be clearly identified and correctly reconciled. Interface designers must recognize and overcome these competing models to successfully bridge the gap between the user's mental model and the system designer's conceptual model of the same target system (Norman, 1983).

F. USABILITY TESTING

Although user testing with real users is the most fundamental usability method, other usability methods can serve as good supplements to gather additional information or gain usability insight at a lower cost. User testing, combined with heuristic evaluation and other usability inspection methods, can provide better efficiency (Nielsen, 1997). Heuristic evaluation consists of finding usability problems in a design by contrasting it with a list of established usability principles. Though this method works very well and produces fast evaluation results, there are always some issues that will be left undiscovered until actual user testing (Nielsen, 1997). In all testing, issues of reliability and validity need serious consideration. Reliability considers whether one would get the same result if a test were repeated and validity considers whether the result actually reflects the usability issues one wants to test.

1. Reliability

Huge individual differences between test users presents a reliability problem with usability testing. It is not uncommon for the best user to be 10 times faster than the slowest user, or the top 25 percent of the users to be twice as fast as the slowest 25 percent of the users (Egan, 1988). Due to this phenomenon, one cannot conclude much from observing a user A using interface X performing a certain task 40 percent faster than user B using interface Y. User B could very well just happen to be slower than user A. If the test were repeated with users C and D, the result could easily be exactly opposite. Often decisions must be made on the basis of fairly unreliable data, which while suspect, is better than having no data at all. Standard statistical tests should be used assess test results and thereby indicate the significance and reliability. Although a 0.05

significance level is often used for research studies, for practical development purposes an 0.20 significance level might be more attainable due to budget and time restraints (Nielsen, 1997).

2. Validity

While reliability can be addressed with statistical tests, a high level of validity requires full understanding of the test method, as well as common sense. Typical validity problems include using the wrong users, giving them the wrong tasks, or not including time restraints of social influences. Confounding effects may also lower the validity of a usability test. An example would be testing the move from a character based user interface to a graphical user interface for an application. If, while running this test, the two competing systems were running on screens set to different pixel graphic displays, the test results may give a comparison between the two size screens rather than the intended character-based versus graphical user interfaces (Nielsen, 1997).

3. Test Users

The primary concern regarding test users is that they should be as representative as possible of the intended users of the system. Sometimes the exact individuals who will be using a system can be identified. Typically, this case is specific to a system being developed for an organization or department within an organization. Another case is a system targeted at a certain type of user, such as lawyers, secretaries or warehouse managers. In this case the users can be more or less homogeneous, but it is desirable to select users from as many different locations as possible. For software intended for the general population, almost anyone can serve as a test user. Lastly, care must also be taken to ensure that both expert, novice, and mid skill level users are chosen (Neilsen, 1997).

4. Test Tasks

Test tasks should be as representative as possible of the uses to which the system will eventually be fielded. They should also reasonably cover the most important parts of the user interface, be small enough to be completed within the test time limits, yet not become trivial. The first task should be extremely simple to guarantee the user an early success experience to boost morale. Conversely, the last task should provide the user with the feeling of accomplishment (Gaylin, 1986).

Usability tests typically have four stages (Nielsen, 1997):

1. Preparation: Ensure the test room is ready and that the computer system is in the start state, and that all test materials and instructions are available.
2. Introduction: Welcome the test user and give a brief expalnation of the purpose of the test, to include computer setup if necessary.
3. Running the test: During the test itself, the experimenter should normally refrain from interacting with the user. The exception to this rule is the case where the test users is clearly stuck and becoming quite unhappy with the situation. Caution must be exercised not to help the user too early.
4. Debriefing: After the test, debrief the user and get any subjective input as soon as possible. During the debrief, extract from the user their input regarding the test itself. Also, as soon as possible, ensure that all results of the test have been collected and properly labeled.

Consideration of the required tasks is critical to properly setting up the test. It is important that the test user feel as if their input is significant, beneficial and appreciated.

5. Performance Measurement

Measurement studies for the basis of much traditional research on human factors. User performance is almost always measured by having a group of test users perform a predefined set of test tasks while collecting time and error data (Nielsen, 1997). There is the potential, however, to measure something that is poorly related to the property which is attempting to be assessed. Goals are generally abstract, so care must be taken to break them down into components with specific usability attributes, which are to be measured by specific tasks. Some usability studies use qualitative methods rather than exact measurements. The focus of the test could be to determine which aspects of the system work well and which are troublesome, yet not have any exact measures to differentiate the two. To mine all possible observations of qualitative data analysis requires extensive engineering experience. Even inexperienced usability engineers, however, can usually ascertain major qualitative findings, as they are more likely to be readily apparent (Nielsen, 1997).

G. SUMMARY

Naval Aviation has made significant strides in reducing the mishap rate in the last half century. These advances can be attributed to more standardized investigation and reporting systems, the use of systems engineering and the application of human error causation theory on mishap cause factors. Significant amounts of data are being collected, cataloged and stored for future reference. Computer database systems make the organization of this data relatively simple. For Naval Aviation to take the next step, however, a robust system for analyzing stored data for trend analysis and prevention is needed.

In an effort to provide a more useful data analysis system, HFACS was developed, then expanded to cover MRMs in HFACS-ME. Proven to be effective in capturing the nature of, and relationships among, latent conditions and active failures. The HFACS-ME taxonomy was developed into a laptop prototype database tool, MEIMS. In a limited usability study, MEIMS was discovered to have great potential. To fully attain its potential, however, MEIMS must be proven to be a user friendly system which fleet users will embrace. Further system development and more rigorous usability testing is required. With proper advances, MEIMS can be especially beneficial in reducing aviation maintenance related mishaps.

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III. METHODOLOGY

A. RESEARCH APPROACH

A desktop investigating, reporting and analysis system focusing on maintenance error in aviation mishaps can greatly advance efforts to enhance safety and reduce mishaps. This information management system's database is populated with historical records of aviation maintenance mishap information. Additionally, a cursory training lesson and a hands-on experience tool are developed which assists the participants in the use of the database. Next, the prototype version of the tool is distributed to two sample groups; one getting the training lesson and an operator's manual and the others getting the training session, an operator's manual, and a hands-on experience session.

Participants in both groups are then provided a prepared task list that required them to navigate through the system. At the completion of the task list, all participants have viewed all portions of the prototype system, and have had the opportunity to form an opinion on its effectiveness. The two groups' performance is evaluated to determine the usefulness of the hands-on experience session in completing the assigned tasks. Additionally, all participants complete an exit survey composed of demographic background questions, opinion items of the prototype system (including improvements), opinion items on the value of the training lesson and the hands-on experience session. They also answer open-ended questions on the prototype system, training session and hands-on experience session.

B. DATA COLLECTION

1. Participants

Students attending the Naval Postgraduate School (Monterey, CA) serve as participants in the study. Most of the participants have recently come from fleet department head tours or embarked airwing staffs. These aviators are from all aircraft communities and within the U.S. Navy and Marine Corps. All have had some experience with mishap information reports and the data contained therein. They are representative of the type of people that will likely be the primary users of the tool. The participants were split into two groups of ten. The groups were distributed evenly matching rank, branch of service, type aircraft flown and years of aviation experience. One group receives a training lesson on the tool along with the instruction manual and the other group gets the training lesson, instruction manual and an additional in depth tutorial.

2. Apparatus

The participants are introduced to the Human Factors Analysis and Classification System-Maintenance Extension (HFACS-ME) taxonomy and to the Maintenance Error Information Management System (MEIMS) prototype data base tool. Additionally, the students have access to three computer labs at the School of Aviation Safety via login ID and password to a group account. Each computer in the laboratories is a Pentium I, Windows 2000 operating system, with 15-inch monitor of 800 x 600 resolution or better. Each has a full functioning prototype of the tool loaded onto it. Prior to logging on, both groups are given a cursory training lesson and instruction manual in the use of MEIMS. Additionally, one group is provided with an additional in depth tutorial in HFACS-ME taxonomy and MEIMS capabilities. After a participant gains access to the computer, the icon “MEIMS Tool” is found on the computer desktop. Once the icon is selected, the prototype opens using Microsoft Access 2000.

3. Instrument

The participant completes a usability test consisting of eleven tasks. After completion of the test, an exit survey is constructed for completion by the participants consisting of three parts: (1) demographics of the participant, (2) Likert-type questions assessing feelings towards the prototype tool (including improvements), the hands-on experience session and tutorial (as applicable), and (3) open-ended items to elicit subjective responses. Participants receiving the tutorial answer additional Likert-type questions and open-ended questions regarding the tutorial. Survey questions are designed to determine if the tool meets user investigation, reporting, and analysis requirements. The survey also queries the participants getting the tutorial in its value. Additionally, participant performance between the two groups is evaluated to determine the effectiveness of the tutorial.

Collection of demographic information is accomplished through the participant selecting from a list of descriptors (squadron, experience with computers, software familiarity, and operating system knowledge). The Likert-type questions use a five point rating scale with verbal anchors: Strongly Agree, Agree, Neutral, Disagree, and Strongly Disagree. Open-ended questions are included to gain inputs on the overall impression of the training lesson, prototype tool, the hands-on experience session, the tutorial (as applicable), and recommendations for improvement.

4. Procedure

MEIMS was revised and updated to include data derived from an available database; a sample group of users will measure its effectiveness. The participants are split into two similar groups. One group is provided an in depth tutorial (See Appendix B) prior to using MEIMS. The perceptions and performance of both groups are measured to determine the value of the MEIMS and the tutorial.

All Participants are given an overview presentation of the study consisting of a projected computer demonstration of the prototype tool and distribution of materials necessary to carry out the user test. The overview consists of:

- Instructions for Accessing the Prototype Tool - information to log on and open the prototype.
- MEIMS Evaluation (Appendix C)--a series of planned navigation routes within the prototype whereby the participant would be able to view the entire system.
- MEIMS Exit Survey (Appendix C)--Participants complete an exit survey composed of demographic background questions, impressions of MEIMS and the tutorial (as applicable) and open-ended question requesting participant's opinions.

All participants perform the above actions: access the prototype tool, navigate the system using the prototype task list, and provide feedback on the system by completing the exit survey. Additionally, the group receiving the tutorial makes comments on its effectiveness and usefulness. The performance of the tutorial group is compared with the non-tutorial group to determine the benefits of the tutorial.

C. DATA TABULATION

The data is transcribed from the survey onto a Microsoft Excel 2000 spreadsheet. The Likert-type questions, based on a five-point scale, are coded into the software (1 through 5) corresponding to the respective anchors (Strongly Disagree, Disagree, Neutral, Agree, and Strongly Agree). Specific categories (MEIMS is: Logical, Easy to Navigate, Very Interesting, Relevant and a Good Concept) are examined for significant differences between the tutorial and non-tutorial groups. Open-ended questions are tabulated by theme and number of responses.

D. DATA ANALYSIS

The data analysis tools of Microsoft Excel 2000 are used to generate descriptive statistics including the mean, standard deviation, and range of the collected data. The performance of the two groups is tabulated, measured and compared. Independent t-tests are conducted on the data to determine significant differences between the tutorial and non-tutorial groups. Participant responses to the open-ended questions are also explored to assess the perceived value of the hands-on experience session, the MEIMS tool itself and the tutorial.

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IV. RESULTS

A. TEST SAMPLE

A usability test was administered to twenty students at the Naval Postgraduate School. They were randomly split into two groups of ten each. Many of the participants (n=17; 85%) were designated Naval Aviators or Naval Flight Officers and represented a cross section of the aviation commands that make up the squadrons in the Navy and Marine Corps. One group of ten received a formal tutorial prior to testing the MEIMS prototype, while the other did not. One of the non-aviators was in the tutorial group, two were not. Both groups were directed to access MEIMS and complete an eleven-item task list. Following the tasks, individual participants were asked to complete an exit survey. The survey consisted of demographic information, queries regarding their satisfaction with MEIMS and queries regarding their satisfaction with the tutorial, if applicable.

B. TEST TASKS

The tasks portion of the test was designed to not only introduce the participants to MEIMS and exercise some of its capabilities, but also to test the effectiveness of the tutorial. The tasks required the participant to access all functional areas of MEIMS. The tasks started relatively simply but became more complex as the participant became more familiar with MEIMS. Test performance is summarized in Table 2.

Table 2: Test Task Performance

	NUMBER OF CORRECT RESPONSES	
TASK	TUTORIAL	NON-TUTORIAL
1	10	10
2	10	10
3	10	10
4	10	10
5	10	10
6	10	7
7	10	10
8	9	6
9	10	10
10	10	10
11	10	10

The first task was accessing the program; all participants (n=20; 100%) were able to access MEIMS with no difficulty. The second task requested the participant's opinion of the main menu. A number of participants from both the tutorial group (n=6; 60%) and the non-tutorial group (n=4; 40%) noted that the tab order was not sequencing properly in the main menu. The third task required the participant to query a type of aircraft and determine how many mishaps exist in the database for that type aircraft. Secondly, the participant had to identify and define the level 3 codes. All participants (n=20; 100%) were able to correctly complete this task. The fourth task asked the participant which of the seven categories was most useful and which was least useful. Aircraft model (n=17; 85%) was considered the most useful, while Location of Mishap and Aircraft Type (n=6; 30%) were each viewed as the least useful.

The fifth task asked the participants to select their own criteria for a multiple query. Some participants (n=5; 25%) created queries that were too restrictive for the limited number of mishaps in the prototype database. Once they viewed the error message that their query was too restrictive, they were able to reselect and complete the query. Both the tutorial (n=8; 80%) group and non-tutorial (n=7; 70%) group thought this feature was extremely useful. The sixth task required the participant to access the HFACS-ME Summary query and determine how many mishaps were in the database. All participants (n=20; 100%) correctly obtained this information. The participant then had to determine how many level one Worker Condition mishaps were in the database and how many level two Medical conditions were in the database. All of the tutorial group (n=10; 100%) correctly answered this question, however not everyone in the non-tutorial group (n=7; 70%) correctly answered it. The seventh task asked the participant to determine the number of mishaps of another type aircraft. All participants (n=20; 100%) correctly determined the number of mishaps.

The eighth task required the participant to determine the number of Detached mishaps in the Mishap Distribution – Location Report. In the tutorial group, almost all (N=9; 90%) correctly answered this question. In the non-tutorial group, over half (n=6; 60%) correctly answered it. The ninth task asked the participant to graph two type aircraft on the X-Axis versus HFACS-Level One codes on the Y-Axis. All participants (n=20; 100%) were able make the graph. Some participants in both the tutorial (n=4; 40%) and the non-tutorial (n=2; 20%) groups noted that the graph provided frequency of mishaps, vice some normalized baseline, like percent of mishaps per type aircraft. The tenth task was to input two mishaps into the database. All members of the both groups (n=20; 100%) were able to successfully enter mishaps into the database. It was noted by many participants in both groups (n=16; 80%) that the database does not adequately error check the information being input.

The eleventh task asked the participant to check the Chronological Listing of the mishaps that had been input into MEIMS. Again, all the participants (n=20; 100%) correctly completed this task. Overall the performance of the tutorial group was slightly better than the non-tutorial group (See Figure 7). In the tutorial group almost all (n=9; 90%) had no errors, while in the non-tutorial group less than half (n=4, 40%) had no errors.

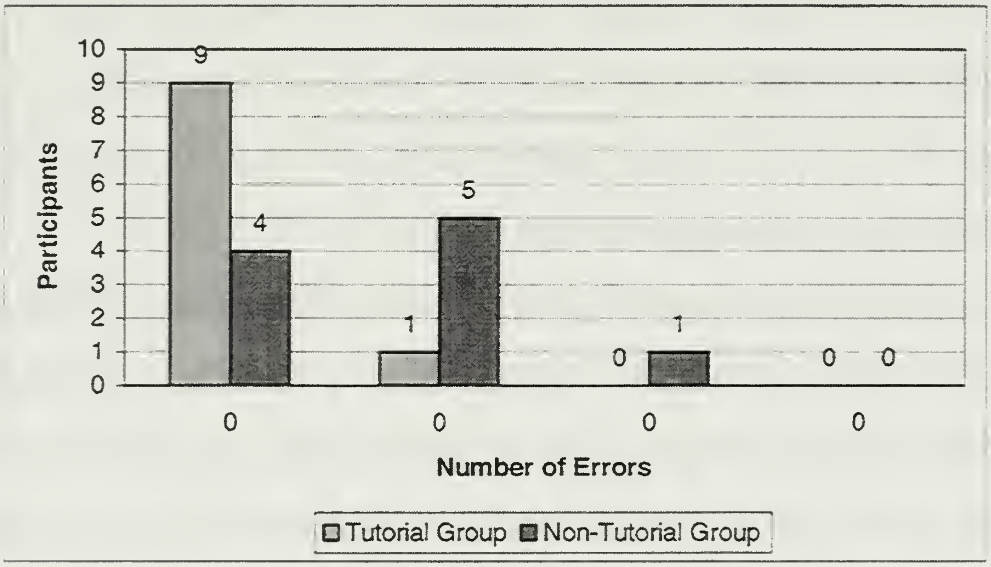

Figure 7: Test Task Performance

The mean percentage of correct responses for the tutorial group was 99.1 (SD = 2.84, RNG = 10), whereas the non-tutorial group mean was 93.7 (SD = 6.07, RNG = 19). An independent t_{equal} test comparing mean tutorial and non-tutorial group performance was conducted. It assumed equal n, no difference between group means, and homogeneity of variance. The observed t_{equal} of 2.55 was significant at the p = 0.02 level for a two tailed test (See table A1, Appendix A). Given the variance for the tutorial group was 8.1 and for the non-tutorial group was 36.9, a second t-test was run for unequal variance to reduce the chance of Type I error. The results are presented in Table 3. The observed $t_{unequal}$ of 2.55 was significant at the 0.02 level.

Table 3: Task Performance Two-Sample t-Test Assuming Unequal Variance

	Tutorial	Non-tutorial
n	10	10
Mean	99.10	93.70
Variance	8.10	36.90
df	13	
t Crit	2.16	
t Stat	2.55	
P two-tail	0.02	

C. DEMOGRAPHIC INFORMATION

Part I of the exit survey requested demographic information from the participants. It established computer experience levels to determine if computer or aviation experience had an impact on that participant's ability to utilize, or their satisfaction with, the MEIMS tool. Demographic information is summarized in Table 4.

Table 4: Demographic Information

Demographic	Number of Participants: Tutorial	Number of Participants: Non-Tutorial
SQDRN MX	9	7
2 + YRS Computer EXP	10	10
Microsoft Office	10	10
Lotus Smart Suite	1	1
Corel Office	0	1
Word Processing	10	10
Presentations	10	10
Graphic Software	10	10
E-Mail	10	10
Database	4	6
Windows (3.1-2000)	10	10
Windows NT	10	10
Macintosh	1	0
Linux	0	1

Question one determined that 9 of the tutorial group participants had been members of aviation units that performed squadron level maintenance (n=9; 90%). The other member of the tutorial group was from a non-aviation background (n=1; 10%). In the non-tutorial group, 7 participants were members of aviation units that performed squadron level maintenance (n=7, 70%), one was a member of a staff that did not perform maintenance (n=1; 10%), and two were from non-aviation backgrounds (n=2; 20). Question two indicated that all participants had at least two years of experience using a computer (n=20; 100%). Question three determined that all participants (n = 20; 100%) were users of Microsoft Office. Minimal numbers in either group had used either Lotus Notes (n = 2; 20%) or Corel/Word Perfect (n = 1; 10%). Question four established a participant's familiarity with different software applications; all participants (n=20; 100%) were familiar with processing, spreadsheet, presentation, and e-mail. In the tutorial group, four were familiar with database applications (n=4; 40%), while in the non-tutorial group, that number was 6 (n=6; 60%). Question five determined that all participants (n=20; 100%) were familiar with Windows 97/2000, Windows NT operating systems, or both. The MEIMS tool was loaded on computers running the Windows NT operating systems.

D. USER SATISFACTION WITH MEIMS TOOL

1. Impressions of MEIMS

Part II of the exit survey requested the participant's impressions of the MEIMS tool and its value to Naval Aviation. Participants responded to five statements using Likert type responses selecting from one of five responses: strongly agree, agree, neutral, disagree, and strongly disagree. Values of five through one respectively were assigned to the statements. Additionally, participants could make subjective comments on any of the statements.

Statement one asked whether or not a participant found MEIMS to be presented in a logical form. The histogram of the frequency distribution for statement one is presented in Figure 8. The mean for the tutorial group was 4.4 (SD = 0.52; RNG = 2), whereas the non-tutorial group mean was 4.1 (SD = 0.57; RNG = 3). All participants in the tutorial group agreed that MEIMS presented the information in a logical fashion (n=10; 100%), while in the non-tutorial group it was less than unanimous (n=9; 90%).

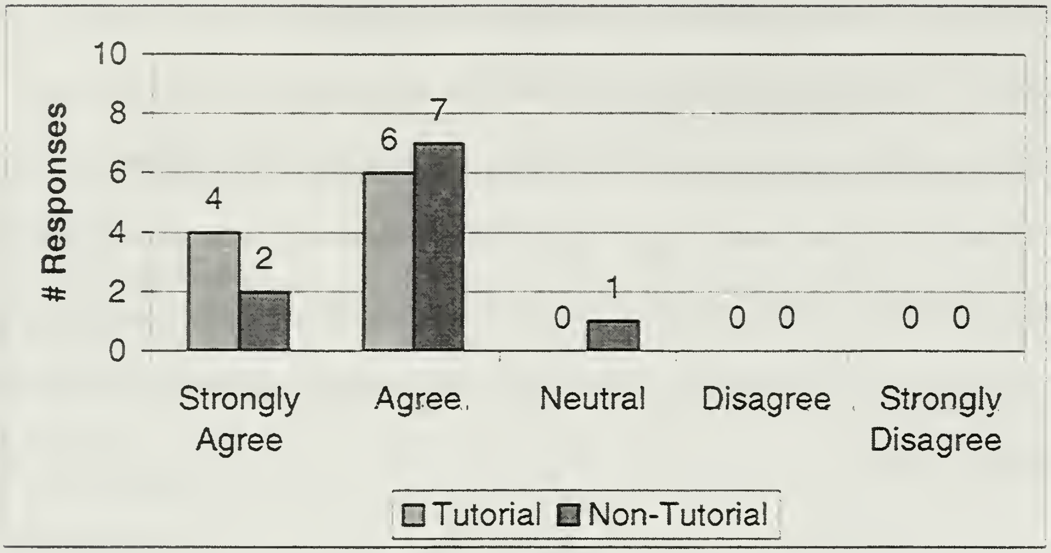

Figure 8: MEIMS is in a Logical Form

Statement two asked about the ease of navigation of the prototype. The histogram of the frequency distribution for statement two is presented in Figure 9. The mean for the tutorial group was 4.0 (SD = 0.5; RNG = 3), whereas the non-tutorial group mean was 3.5 (SD = 0.97; RNG = 4). A majority of participants in both the tutorial group (n=9; 90%) and the non-tutorial group (n=6; 60%) agreed that MEIMS was easy to navigate.

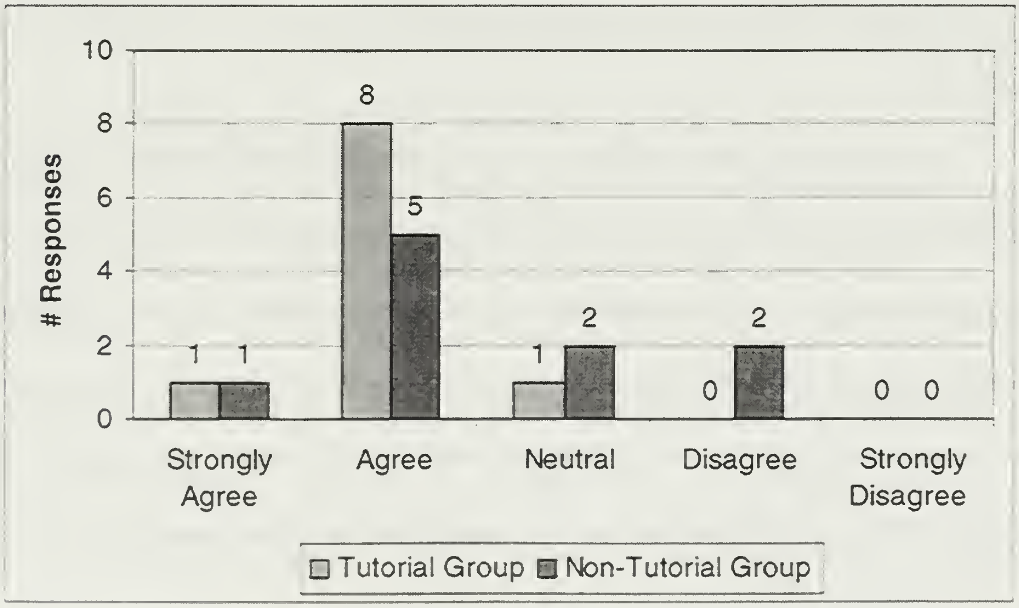

Figure 9: MEIMS is Easy to Navigate

Statement three asked if the participants felt MEIMS was "very interesting." The histogram of the frequency distribution for statement three is presented in Figure 10. The mean for the tutorial group was 4.2 (SD = 0.63; RNG = 3), whereas the non-tutorial group mean was 3.7 (SD = 0.82; RNG = 4). Most participants in both the tutorial group (n=9; 90%) and the non-tutorial group (n=7; 70%) agreed that MEIMS was very interesting.

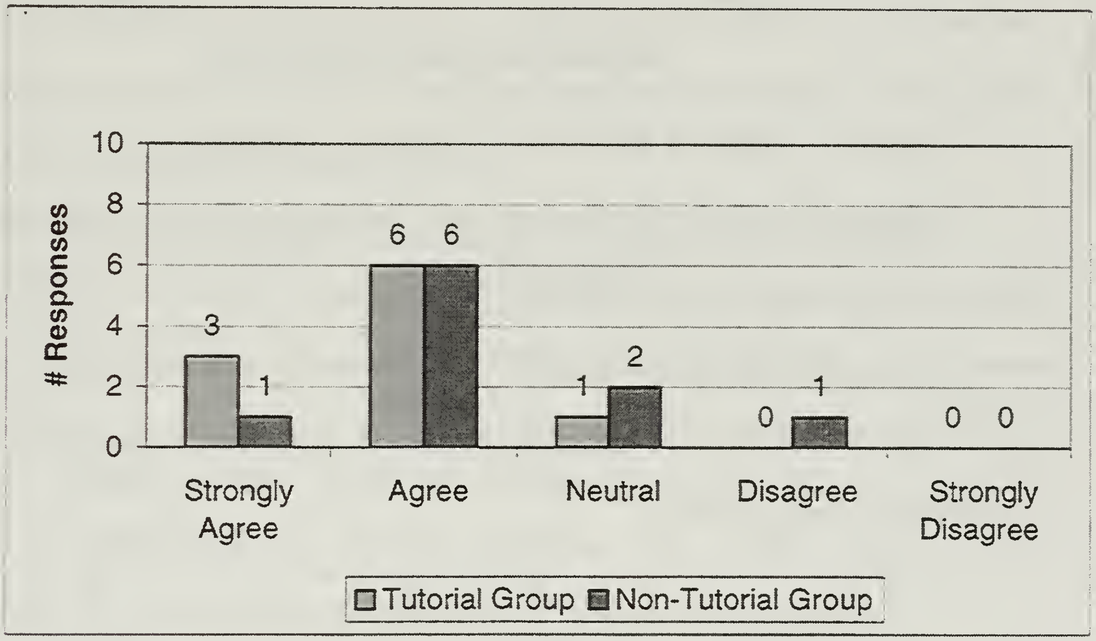

Figure 10: MEIMS is Very Interesting

Statement four asked about the relevance of MEIMS to aviation maintenance operations. The histogram of the frequency distribution for statement four is presented in Figure 11. The mean for the tutorial group was 4.6 (SD = 0.52; RNG = 2), whereas the non-tutorial group mean was 4.5 (SD = 0.53; RNG = 2). All participants agreed that MEIMS was relevant (n=20; 100%).

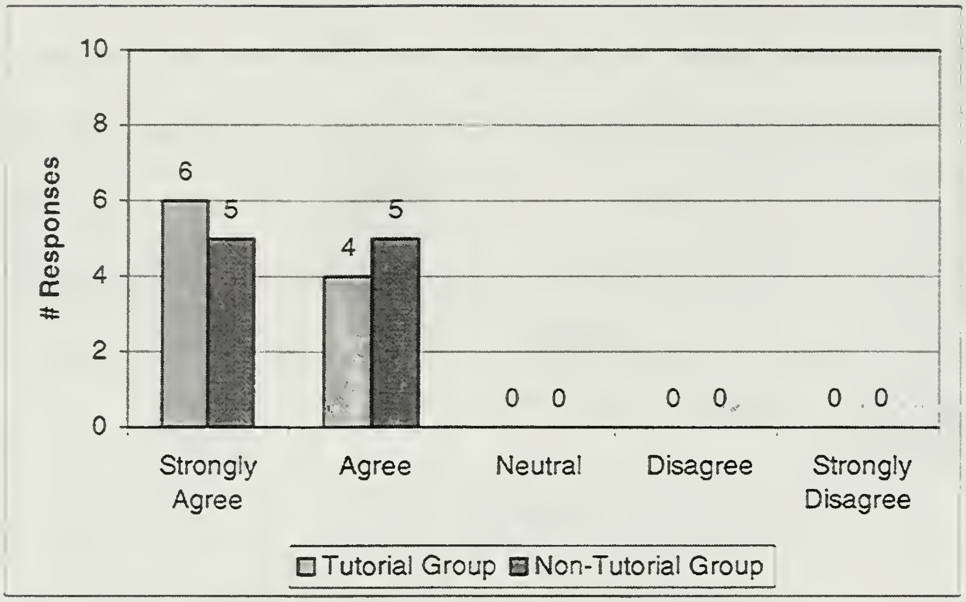

Figure 11: MEIMS is Relevant to Maintenance Operations

Statement five asked whether prototype concept was a good one. The histogram of the frequency distribution for statement five is presented in Figure 12. The mean for the tutorial group was 4.6 (SD = 0.52; RNG = 2), whereas the non-tutorial group mean was 4.5 (SD = 0.53, RNG = 2). Again, all participants agreed that the concept of MEIMS was a good one (n=20; 100%).

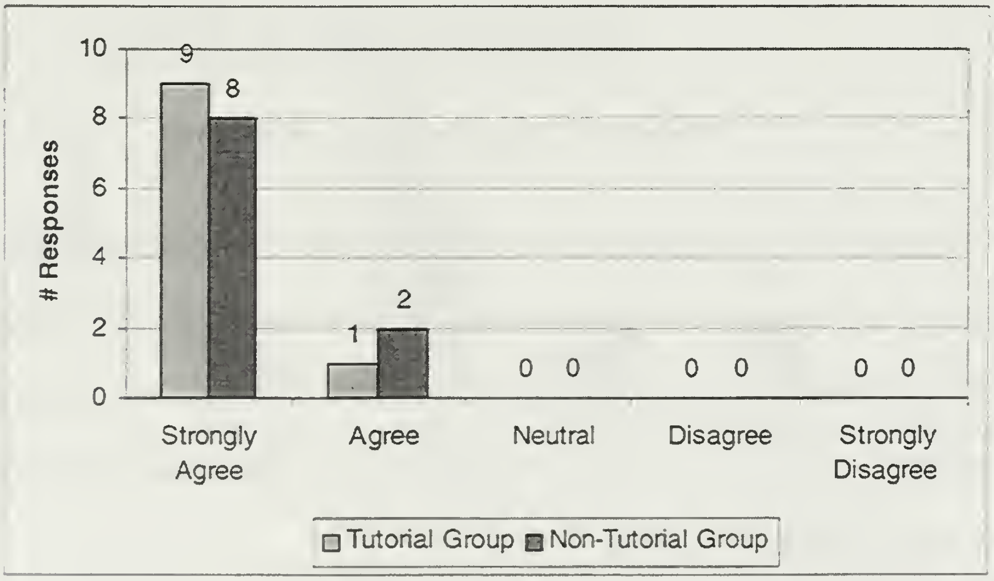

Figure 12: MEIMS Concept is Good

Independent t_{equal} tests comparing tutorial and non-tutorial responses to the Likert-type questions were conducted. They assumed equal n, no difference between group means, and homogeneity of variance (See Appendix A). For the Logical, Navigation, Relevance and Concept categories, no significant difference was noted. For the Interesting category, an observed t_{equal} of 2.59 was significant at the $p = 0.02$ level for the two tailed test (See table A4, Appendix A). Given the variance for the tutorial group was 0.28 and for the non-tutorial group was 0.68, a second t-test was run for unequal variance to reduce the chance of Type I error. The results are presented in Table 5. The observed $t_{unequal}$ of 2.59 was significant at the 0.02 level.

Table 5: MEIMS is Interesting Two-Sample t-Test Assuming Unequal Variance

	Tutorial	Non-tutorial
n	10	10
Mean	4.50	3.70
Variance	0.28	0.68
df	15	
t Crit	2.13	
t Stat	2.59	
P two-tail	0.02	

2. Open-ended Questions

Part III of the exit survey contained three open-ended questions regarding the participants overall satisfaction with MEIMS. All participants made constructive criticism, although overall, the response was very positive. The comments indicated that

MEIMS is currently a good tool that has the potential to be extremely valuable instrument in the prevention of mishaps (See Table 6)

Question one asked the participant to list the most positive aspects of the prototype. Overall, the response was positive. Twelve participants commented to the effect that MEIMS would make an immediate, positive impact on safety in the fleet.

Question two asked for the most negative aspects of the prototype. Most comments were problems or suggested improvement to the interface. Such items included error checking capability for data input, enlarge text boxes so the data can be completely read, line wrap the Contributing Factors text box so that the factors are not cut off after one line, and improving the tab function in the main menu, improve the page to page navigation. Numerous suggestions were made for “normalizing” the graphing functions. Several participants suggested a “find” mode in reports to prevent paging through them to find the data desired. Responses produced no discernable difference between the tutorial and non-tutorial groups regarding their impression of MEIMS.

Familiarity and knowledge of HFACS-ME terminology, however, was a distinct problem for several of the non-tutorial group. Seven participants made some comment regarding HFACS-ME terminology. Most found it hard to understand. Conversely, none of the tutorial group, to whom the HFACS-ME terminology was thoroughly explained, had a negative comment regarding HFACS-ME terminology.

Question three requested suggestions for changes to MEIMS. Most participants re-iterated their previously mentioned “negatives.” One participant made the suggestion that the database should cross-reference the MIR messages for each mishap. Seventeen made suggestions regarding navigation, error checking and GUI interface. One participant mentioned making MEIMS available on the World Wide Web. There were no noteworthy differences between the tutorial and non-tutorial groups in response to this question.

Table 6: Responses to Open Ended Questions

Theme	Number of Responses	
	Tutorial	Non-tutorial
Positive Impact	5	7
Normalize Graphs	4	2
Find Mode in Reports	2	3
HFACS Terminology Difficult	0	7
Improve Error Checking For Data Entry	9	6
Improve Navigation	4	6
Link to MIR message	1	0
GUI Improvements	8	9

E. USER SATISFACTION WITH THE TUTORIAL

1. Impressions of the Tutorial

Part IV of the exit survey requested the participant's impressions of the tutorial. Participants responded to five statements using Likert-type responses selecting from one of five responses: strongly agree, agree, neutral, disagree, and strongly disagree. Values of five through one respectively were assigned to the statements. Additionally, participants could make subjective comments on any of the statements (See Table 7)

Table 7: Summary of Responses to Tutorial

Tutorial	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
Beneficial	3	6	1	0	0
Made Eval Easier	6	3	0	1	0
Interesting	5	5	0	0	0
Relevant	8	2	0	0	0
Good Concept	6	4	0	0	0

Statement one asked whether the tutorial was beneficial. The histogram of the frequency distribution for statement one is presented in Figure 13. The mean for the tutorial group was 4.2 (SD = 0.63; RNG = 3). All but one participant in the tutorial group agreed that the tutorial was beneficial (n=9; 90%). The participant that was neutral commented that a user could figure MEIMS out in "15-30 minutes" without the benefit of the tutorial.

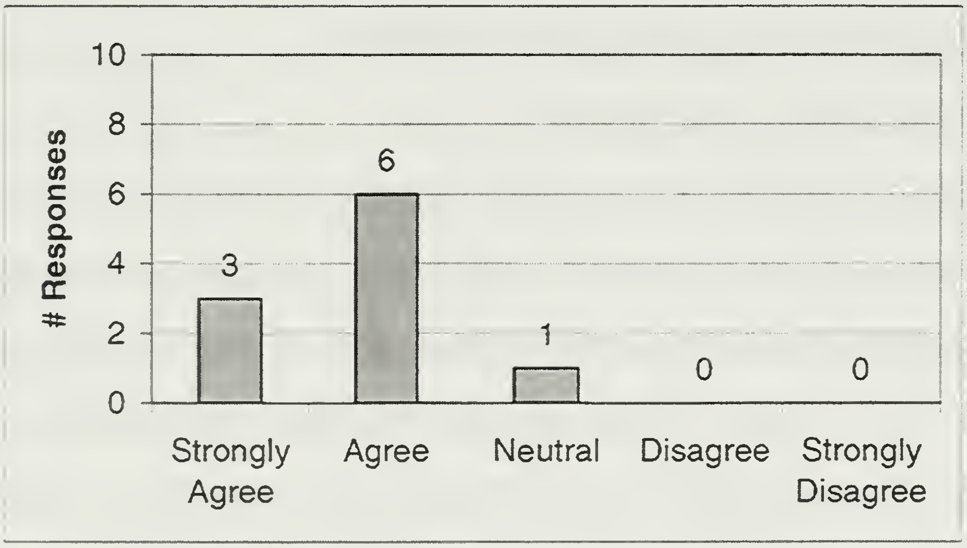

Figure 13: Tutorial is Beneficial

Statement two asked if the tutorial made the usability test easier to complete. The histogram of the frequency distribution for statement two is presented in Figure 14. The mean for the tutorial group was 4.54 (SD = 0.93; RNG = 4). Almost all of the participants in the tutorial group (n=9; 90%) considered the tutorial to be beneficial. The participant that disagreed restated the reason given in the item above.

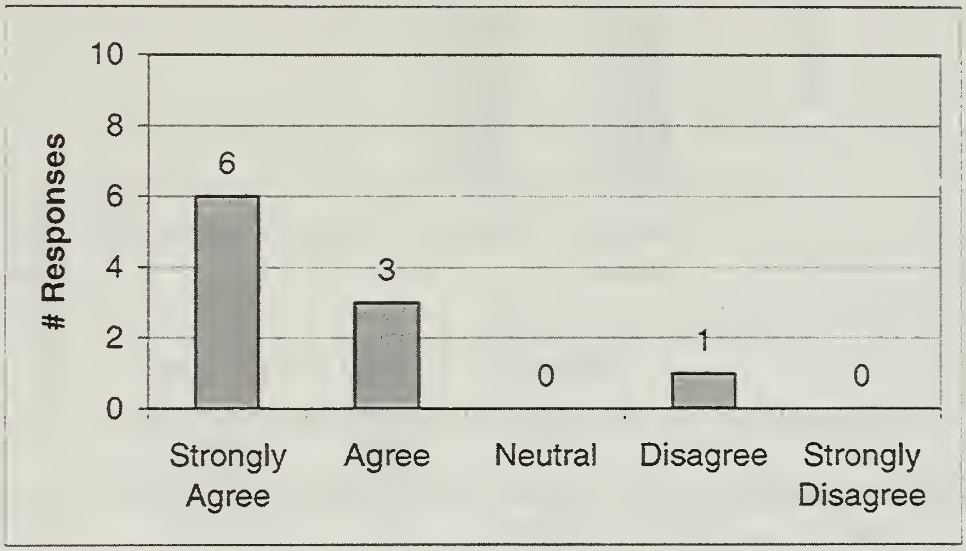

Figure 14: Tutorial Made Evaluation Easier

Statement three asked if the participants felt the tutorial was interesting. The histogram of the frequency distribution for statement three is presented in Figure 15. The mean for the tutorial group was 4.5 (SD = 0.53; RNG = 2). All participants in the tutorial group found it to be interesting (n=10; 100%).

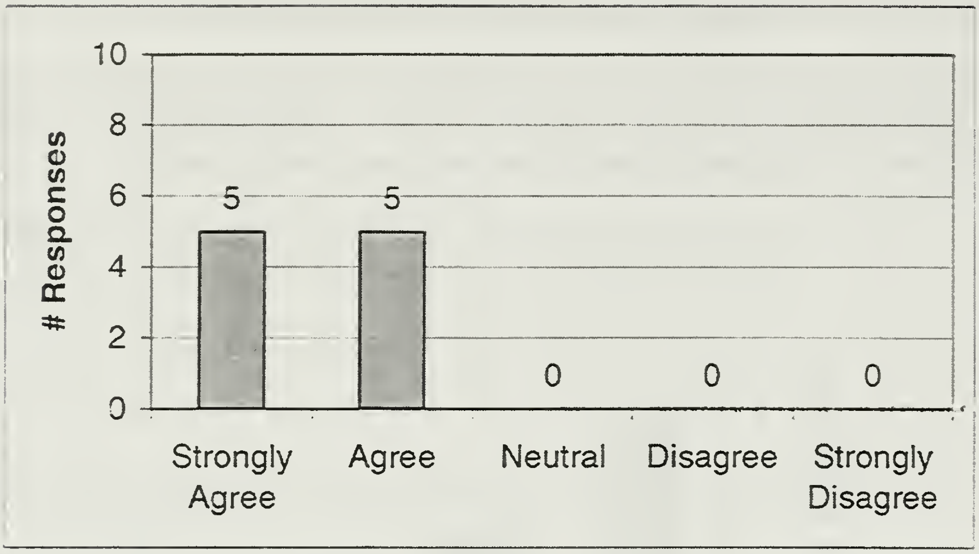

Figure 15: Tutorial is Interesting

Statement four asked about the relevance of tutorial to MEIMS. The histogram of the frequency distribution for statement four is presented in Figure 16. The mean for the tutorial group was 4.8 (SD = 0.42; RNG = 2). All participants agreed that the tutorial was relevant to MEIMS (n=10; 100%).

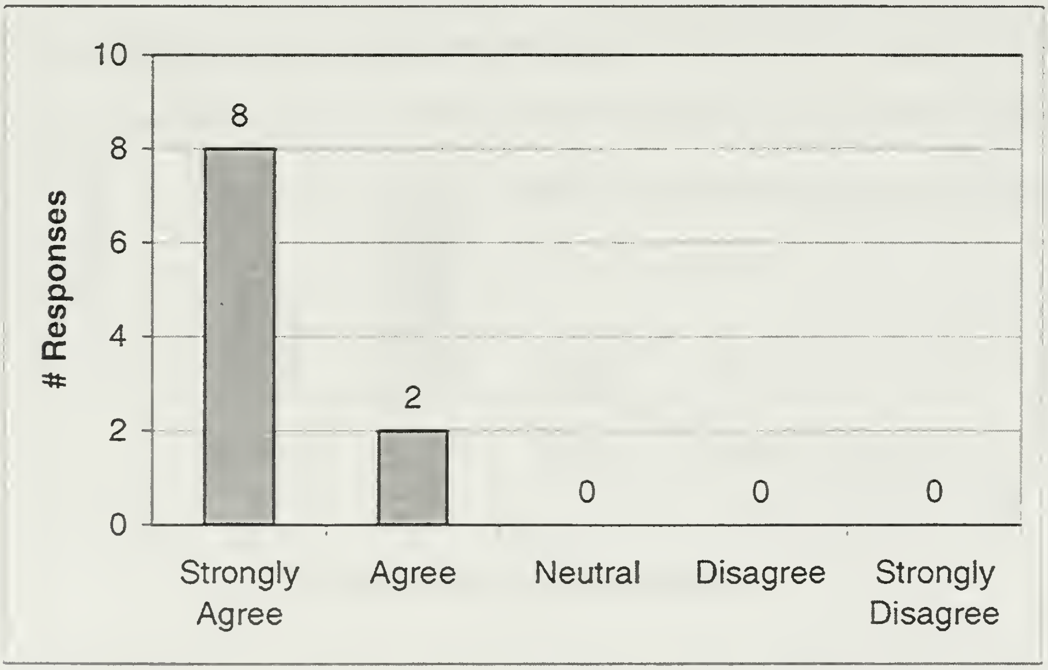

Figure 16: Tutorial Relevant to MEIMS

Statement five asked whether the concept of a tutorial was a good one. The histogram of the frequency distribution for statement five is presented in Figure 17. . The mean for the tutorial group was 4.6 (SD = 0.52; RNG = 2). Again, all participants agreed that the tutorial concept was a good one (n=10; 100%).

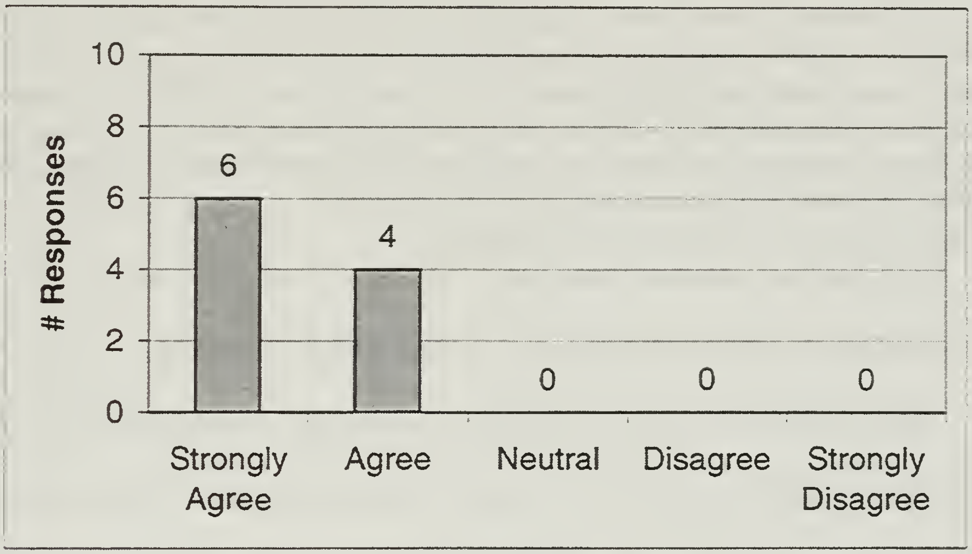

Figure 17: Tutorial Concept is Good

2. Open-ended Questions

The last portion of the exit survey contained three open-ended questions regarding the participants overall satisfaction with the tutorial. The participants were asked about the positive and negative aspects of the tutorial. Lastly, the participants were encouraged to suggest changes to the tutorial. The comments made were overall positive. Some constructive criticism was made, aimed at making the tutorial better.

Question one asked the participant to list the most positive aspects of the tutorial. Comments referred to the tutorial as “comprehensive,” “focused on the user,” and “providing the necessary background” to take the test. One participant stated that the tutorial was thorough without running too long.

Question two asked for the most negative aspects of the tutorial. There were fewer negative comments than positive ones. They included deleting the historical references in the beginning of the tutorial, making the slides "less busy," and too much redundancy of the HFACS-ME codes.

Question three requested suggestions for changes to the tutorial. There was only one comment made regarding changes to the tutorial (n=1; 10%). It was suggested that the tutorial should be self-study, providing the participant either the slides (with notes), or on a desktop from which to view the tutorial.

V. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

A. SUMMARY

Naval Aviation is in the unenviable position of increased demand for high levels of operational readiness, equipment availability, and personnel training within a climate of reduced budgets. The notion of doing more with less is an everyday reality. To meet this demand, asset preservation is vitally important, as funding for replacements does not appear likely in the near future. In this fiscally strained environment, the costs of Naval Aviation mishaps, in terms of mission capability, operational readiness, and material status, are too high. Reducing the number and rate of mishaps occurrence is paramount to the success of Naval Aviation. Furthermore, reducing "avoidable" mishaps, those involving human error, is an absolute must. Human error in aviation mishaps must be identified, and appropriate intervention strategies developed, aimed at reducing the causes of those errors. Conventional accident causation theories suggest that accidents are the result of a complex combination of errors. Naval Aviation must target intervention strategies in key areas to effectively combat human error.

Initial efforts were made solely in the area of aircrew error reduction, and a robust classification taxonomy, Human Factors Analysis and Classification System (HFACS) was developed. It was soon realized that to meet the goals in mishap reduction, Naval Aviation had to look beyond aircrew error and study maintenance human error. To that end a Maintenance Extension, HFACS-ME was built. This expanded taxonomy proved to be an acceptable method for classifying human factors in maintenance mishaps. Using HFACS-ME to study mishap causes, a clear picture of the human factors contributing to mishaps can be drawn.

To fully utilize the HFACS-ME taxonomy, a prototype database tool, Maintenance Error Information Management System (MEIMS) was created. It enables better access to the data, query, graphing and reporting functionality, and the ability to add new information to the database. In an initial usability study, MEIMS was determined to be a valuable tool in the effort to reduce human error in maintenance. A MEIMS revision was completed, updating and improving it, and targeting many of the issues detailed in the initial usability test. Additionally, a users tutorial was built to assist the targeted user in the introduction to MEIMS. This study investigated the validity of the MEIMS tool and the tutorial. MEIMS is developing into a robust tool not only for the analysis of mishap causal factors, but also an effective weapon in the development of prevention programs tailored to human error in maintenance mishaps. Its positive impact on the fleet will be immediate and far-reaching.

B. CONCLUSIONS

The participants of the study were overwhelmingly supportive of MEIMS and the tutorial. Results from the usability test and the Likert-type responses indicate that the tutorial was beneficial and made the test easier. Participants in the tutorial group performed better in the tasks portion than the non-tutorial group. Based upon the independent t-tests conducted, there was a significant performance difference between the two groups, with the tutorial group performing better. The response to the Likert-type questions did not indicate a significant difference between the tutorial and non-tutorial groups (as determined by independent t-test) regarding MEIMS being logical, easy to navigate, relevant to maintenance operations and a good concept. Regarding MEIMS being interesting, an independent t-test indicated a significant difference between the tutorial and non-tutorial groups, with the tutorial group finding MEIMS more interesting. This data indicates an increasing interest level with increased exposure and knowledge of MEIMS. The tutorial group's support for MIEMS was more enthusiastic. Although both groups strongly advocated MEIMS relevance to maintenance operations and endorsed it as a good concept, the tutorial group was more positive in supporting it. The participants of the tutorial provided excellent feedback and also solidly endorsed it as a complimentary link with MEIMS.

All participants made valuable comments and suggestions. Numerous previously unrecognized GUI deficiencies were identified. Additionally, data error checking, graphing and reporting anomalies were detailed. Most beneficial, however, were the suggestions to make MEIMS a better product for the fleet. Specifically linking date-time-groups of mishap investigation reports to MEIMS was an especially astute suggestion. Also, suggesting MEIMS for the World Wide Web, a pre-planned progression for future iterations, was certainly perceptive.

The potential of MEIMS is expansive. MEIMS should be expanded to include other services, allies and NATO mishap information to broaden the scope from which data is drawn. Efforts are ongoing to make a variation of MEIMS that would include civilian and commercial aviation. That would enable military users an even larger pool of information from which to draw data and will be helpful in providing insights and parallels between military and civilian/commercial aviation safety. MEIMS should soon be available on the World Wide Web. It will be an excellent tool for users, from Naval

Aviation's highest executive levels down to squadron work centers, to derive information and to provide the necessary tools to prevent maintenance related mishaps.

C. RECOMMENDATIONS

For any software tool to be effective, it must be considered easy to use and effective. That notion is especially critical in a tool which the fleet is expected to use. If it is not easy to use and effective, it will remain on the shelf. To that end, the following recommendations are made for the MEIMS tool:

- Include the tutorial as a part of MEIMS, upgrading as necessary
- Provide better navigation from MEIMS functions to the main menu
- Improve GUI anomalies including the tab function on the main menu, improving text boxes so that all data can be read by the user
- Improve the query causal factors to add text wrap, so mishap information will not be cut off.
- Provide better error-checking during data input
- Add a find mode in the reports function to enable the user to quickly access the desired data without paging through the report.
- Normalize graph presentations to provide a "weighted" view of data
- Provide more sub-menus to expedite multi-layer functionality
- Increase the volume of the database to include more mishaps
- Provide a link to the date-time-group of the Mishap Investigation Report
- Make MEIMS and the tutorial available over the World Wide Web

MEIMS is already a robust tool for analyzing and reporting data regarding maintenance human error. Making the above improvements will make it an even better tool. Once it is available on-line with the proper training, it should be a well-used tool in the effort to preserve lives, material and readiness.

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APPENDIX A

T-TEST RESULTS FOR MEIMS EVALUATION AND PART II OF EXIT SURVEY

1. MEIMS TASK PERFORMANCE

The following is the complete t-test results from the MEIMS evaluation assuming equal n and variance.

Table A1: Test Task Performance Two-Sample t-Test

	Tutorial	Non-tutorial
n	10	10
Mean	99.10	93.70
Variance	8.10	36.90
Pooled Variance	22.50	
df	18	
t Crit	2.10	
t Stat	2.55	
P two-tail	0.02	

2. LIKERT-TYPE QUESTION RESPONSE

The following are the complete t-test results from each of the Likert-type questions from Part II of the Exit Survey. The t-tests assume equal n and variance.

Table A2: MEIMS is in a Logical Form Two-Sample t-Test

	Tutorial	Non-tutorial
n	10	10
Mean	4.40	4.10
Variance	0.27	0.32
Pooled Variance	0.29	
df	18	
t Crit	2.10	
t Stat	1.24	
P two-tail	0.23	

Table A3: MEIMS is Easy to Navigate Two-Sample t-Test

	Tutorial	Non-Tutorial
n	10	10
Mean	4.00	3.50
Variance	0.22	0.94
Pooled Variance	0.58	
df	18	
t Crit	2.10	
t Stat	1.46	
P two-tail	0.16	

Table A4: MEIMS is Very Interesting Two-Sample t-Test

	Tutorial	Non-tutorial
n	10	10
Mean	4.50	3.70
Variance	0.28	0.68
Pooled Variance	0.48	
df	18	
t Crit	2.10	
t Stat	2.59	
P two-tail	0.02	

Table A5: MEIMS is Relevant to Maintenance Operations Two-Sample t-Test

	Tutorial	Non-tutorial
n	10	10
Mean	4.60	4.50
Variance	0.27	0.28
Pooled Variance	0.27	
df	18	
t Crit	2.10	
t Stat	0.43	
P two-tail	0.67	

Table A6: MEIMS Concept is Good Two-Sample t-Test

	Tutorial	Non-tutorial
n	10	10
Mean	4.90	4.80
Variance	0.10	0.18
Pooled Variance	0.14	
df	18	
t Crit	2.10	
t Stat	0.60	
P two-tail	0.56	

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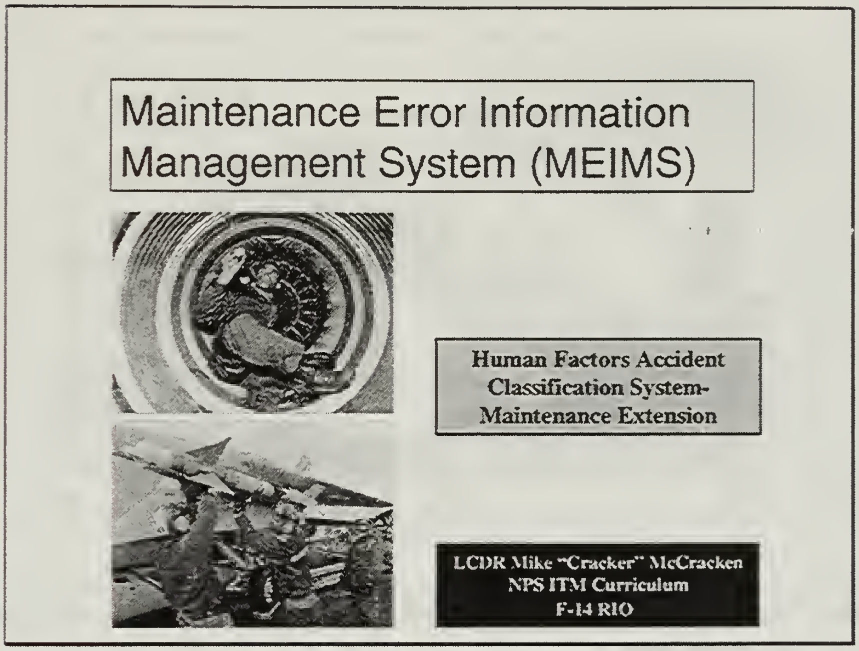
APPENDIX B

MEIMS TUTORIAL PRESENTATION WITH NOTES

Slide 1



Maintenance Error Information Management System (MEIMS)

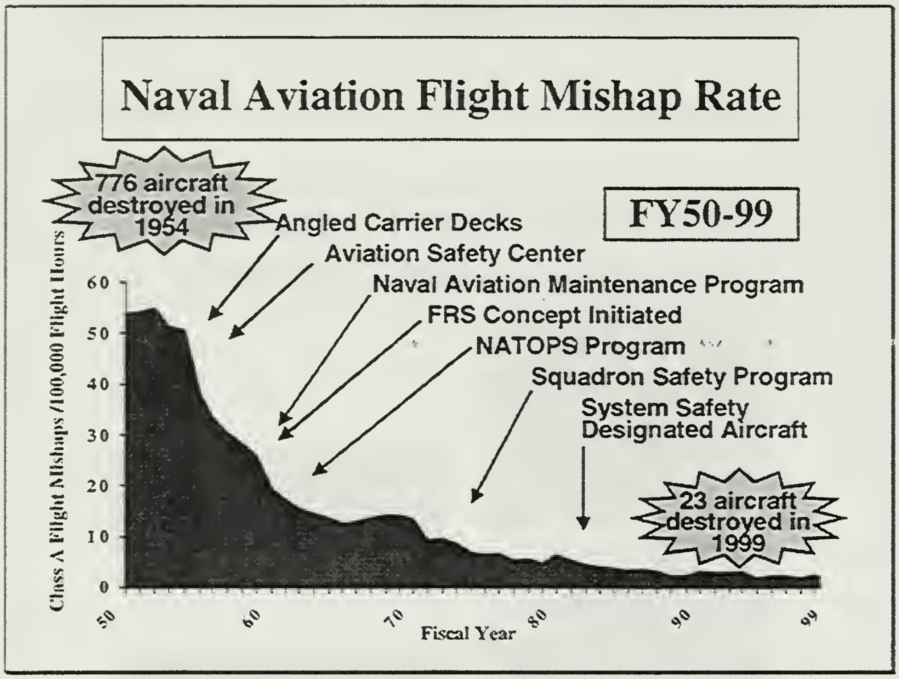
Human Factors Accident Classification System-
Maintenance Extension

LCDR Mike "Cracker" McCracken
NPS ITM Curriculum
F-14 RIO

(Ensure that the students have copies of these presentation slides to use as a reference during the presentation)

Welcome to the Maintnenancee Error Information Management System (MEIMS) brief. This prototype tool is built upon the Navy's HFACS-ME (Human Factors Accident Classification System- Maintenance Extension) taxonomy. This presentation will detail the HFACS-ME model in detail, explain terminology and provide details. Please pay close attention and ask questions as necessary. After explaining the HFACS-ME taxonomy, the MEIMS tool, built upon that taxonomy, will be briefed and demonstrated.

Slide 2



Naval Aviation Flight Mishap Rate

FY50-99

776 aircraft destroyed in 1954

Angled Carrier Decks
Aviation Safety Center
Naval Aviation Maintenance Program
FRS Concept Initiated
NATOPS Program
Squadron Safety Program
System Safety Designated Aircraft

23 aircraft destroyed in 1999

Naval aviation has become considerably safer over the last few decades, but there is still a need for improvement.

This chart shows the significant reductions in Naval Aviation mishap rates (per 100,000 flight hours) since 1950.

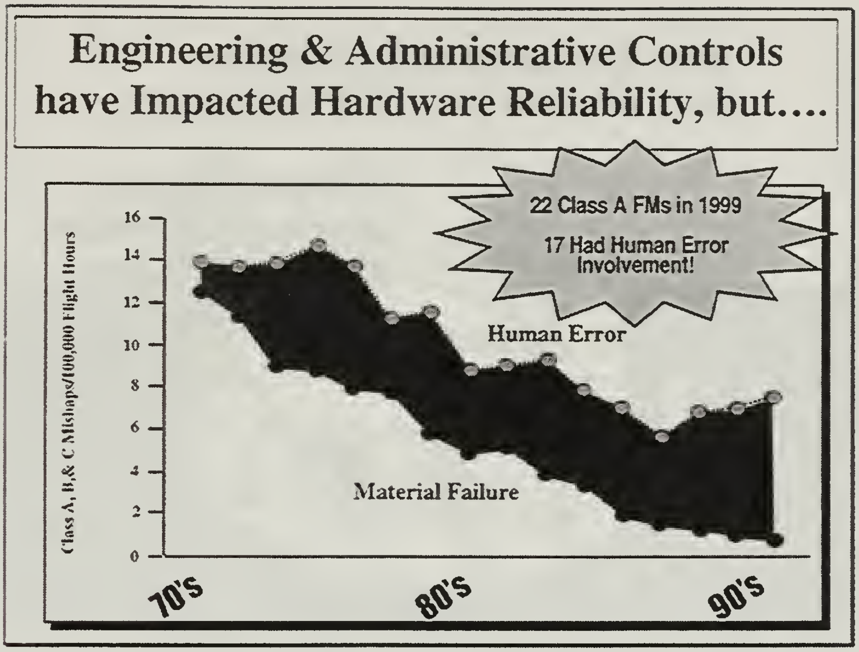
Improvements in Naval Aviation safety have primarily focused on engineering and administrative controls. They have included (but have not been limited to) design improvements (angled carrier decks), the creation of the Naval Safety Center, improved maintenance programs (NAMP), training (FRS, NATOPS), local safety programs, and system safety designated aircraft.

The Mishap rate has actually been cut in half each decade since 1950, HOWEVER, there are still many Class A mishaps each year (155 total Class A's for FY 95-99) which result in unacceptable loss of life, disabling injuries, and hundreds of millions of dollars in damages. So, again, improvements are necessary.

FY 95-99 Total Navy/Marine Aviation Class A Mishaps

	Flight Hours	Flight Mishaps	Rate
FY95	1,656,450	34	2.05
FY96	1,650,026	36	2.18
FY97	1,523,507	27	1.77
FY98	1,518,109	36	2.37
FY99	1,527,186	22	1.44
FY95-99	7,875,278	155	1.97

Slide 3



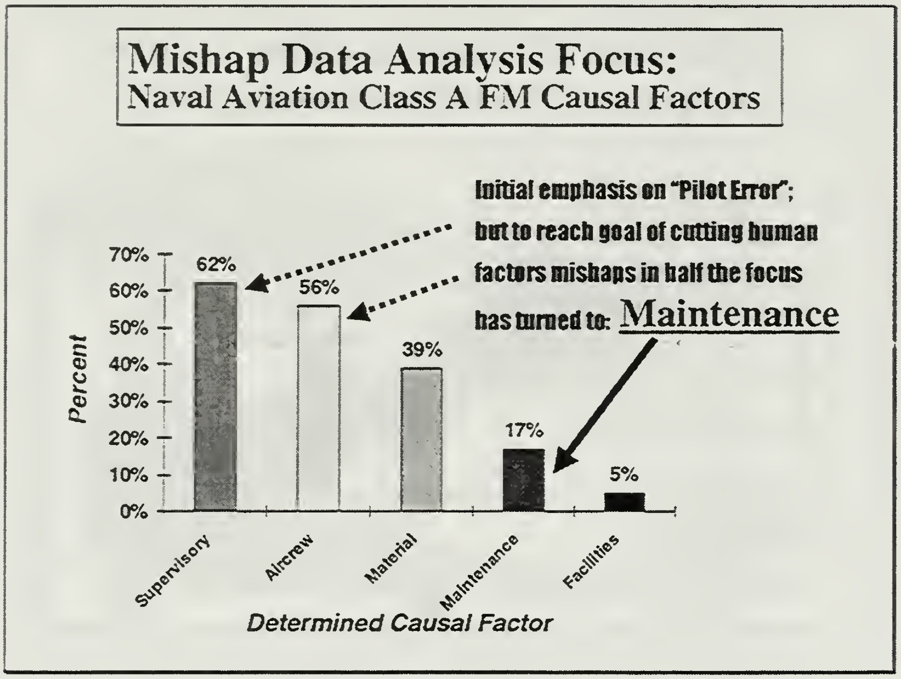
Engineering & Administrative Controls have Impacted Hardware Reliability, but....

Engineering and administrative controls have significantly impacted hardware reliability (the aircraft/machinery are more reliable), but mishaps still occur. Why?

This chart shows that over the last three decades, the material factors that cause mishaps (e.g., machine reliability) have steadily decreased. Human error has also decreased (with training, proper supervision, etc.), but at a slower rate so that it has resulted in a higher percentage of the factors that cause mishaps. **In fact, the percentage of human errors in mishaps is now increasing.**

In 1999, there were 22 Class A Flight Mishaps; 17 had human error involvement (77%).
Again, there were 155 Navy/Marine Class A's for FYs 95-99!

Slide 4



Mishap Data Analysis Focus:
Naval Aviation Class A FM Causal Factors

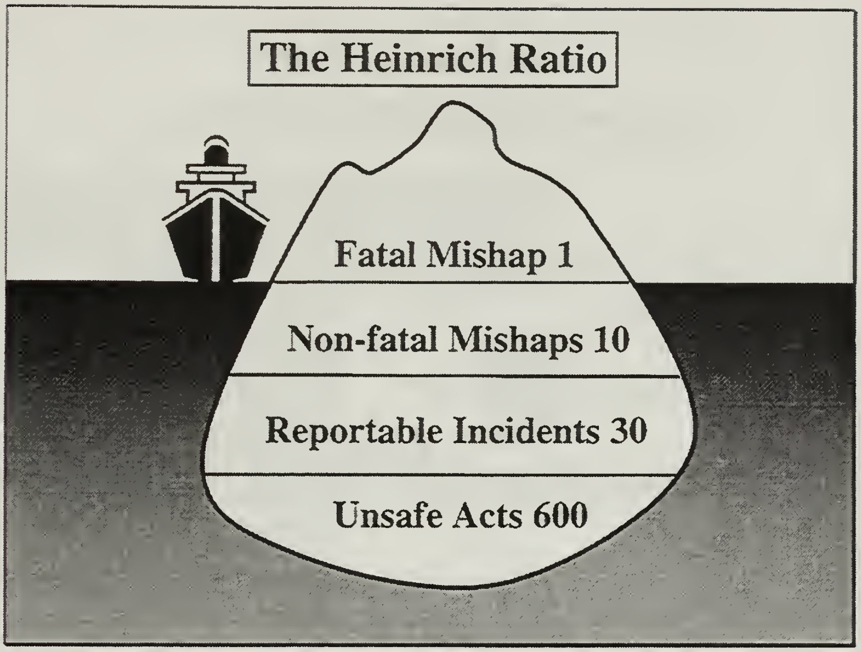
Initial emphasis on "Pilot Error"; but to reach goal of cutting human factors mishaps in half the focus has turned to: Maintenance

(NOTE: Mishaps are caused by more than one factor, therefore, the chart percentages total more than 100%)

To further reduce the mishap rate, we must identify and correct the causes of mishaps.

Human error is involved in the majority of the determined causal factors in this chart, with material failures listed in 39% of the mishaps. Human error preventative measures have primarily been concentrated on aircrew and supervisory issues (e.g., training, SOPs). However, to reach the Human Factors Quality Management Board's goal of reducing mishaps by 50%, we must also focus on maintenance errors.

Slide 5



The Heinrich Ratio

Fatal Mishap 1

Non-fatal Mishaps 10

Reportable Incidents 30

Unsafe Acts 600

We have just reviewed some statistics on major mishaps; however, MAJOR ACCIDENTS ARE ONLY THE TIP OF THE ICEBURG.

To make significant improvements in aviation maintenance error, we must thoroughly analyze the major mishaps. Fortunately, major accidents (Class A mishaps) are relatively rare events. However, this low mishap rate poses a new problem. There is simply not enough information available from Class A mishaps to conduct an effective trend analysis.

Solution: For every Class A mishap, there are numerous Class B, Class C, and hazard reports which have similar cause factors. We must, therefore, thoroughly investigate the "minor accidents" as well as the "majors" to discover these causes.

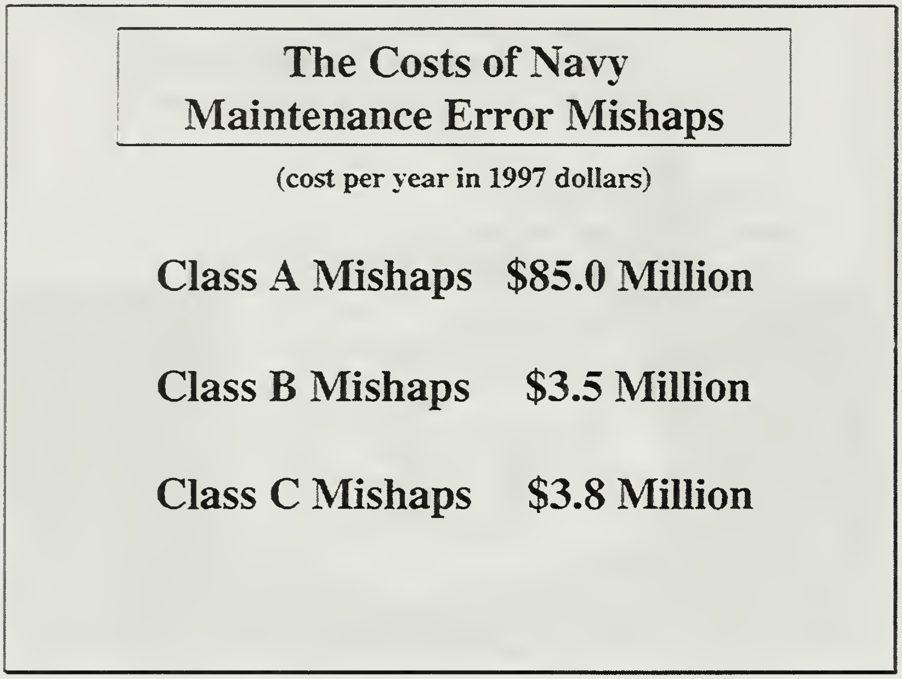
Heinrich Ratio

The relatively few number of catastrophic accidents are the "tip of the iceberg". For every major mishap, there are 10 less serious accidents, 30 incidents, and 600 hazardous acts. The circumstances (cause factors) which raise the severity of the accident are identifiable in all levels of accidents through adequate investigation.

Source:

Heinrich, H.W., Petersen, D. & Roos, N. (1980). Industrial Accident Prevention: A Safety Management Approach (5th ed.) New York: McGraw-Hill. Retrieved from http://hfskyway.faa.gov/training_toc.htm (MRM training site).

Slide 6



The Costs of Navy Maintenance Error Mishaps

(cost per year in 1997 dollars)

Class A Mishaps	$85.0 Million
Class B Mishaps	$3.5 Million
Class C Mishaps	$3.8 Million

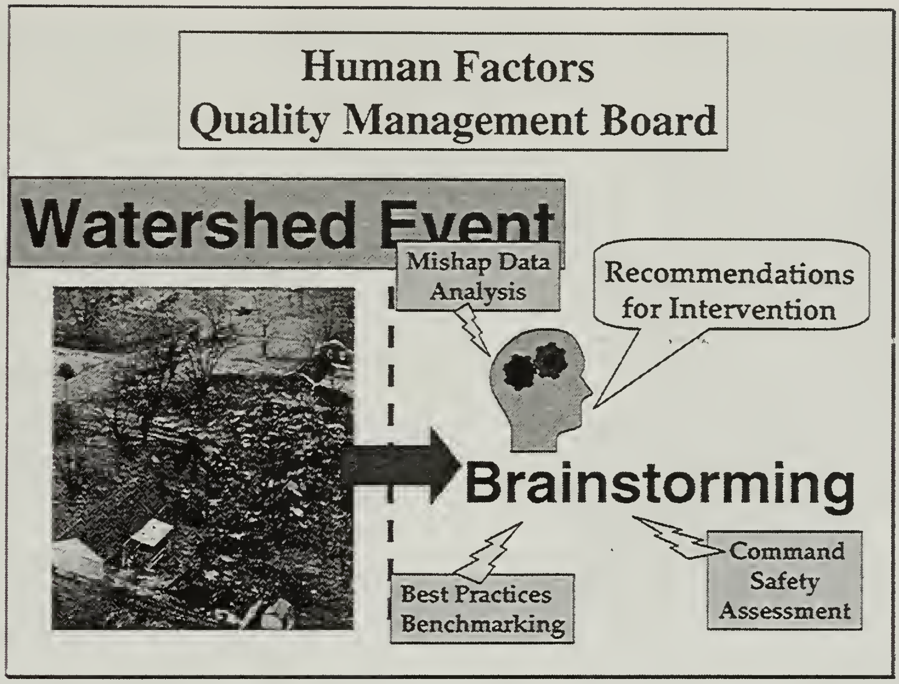
The Costs of Navy Maintenance Error Mishaps.

The costs are calculated from the FY90-97 Maintenance Related Mishaps and adjusted to 1997 dollars.
NOTE: This only includes component replacement costs and man hours to restore the aircraft in operating condition. It does not include personal injury, loss of life, property damages or liability.

Class A	$85.0 million/year
Class B	$3.5 million/year
Class C	$3.8 million/year

Source: Aircraft Maintenance Human Factors PAT report to the Safety QMB, 27 June 1998.

Slide 7



Human Factors
Quality Management Board

Watershed Event

Mishap Data Analysis

Recommendations for Intervention

Brainstorming

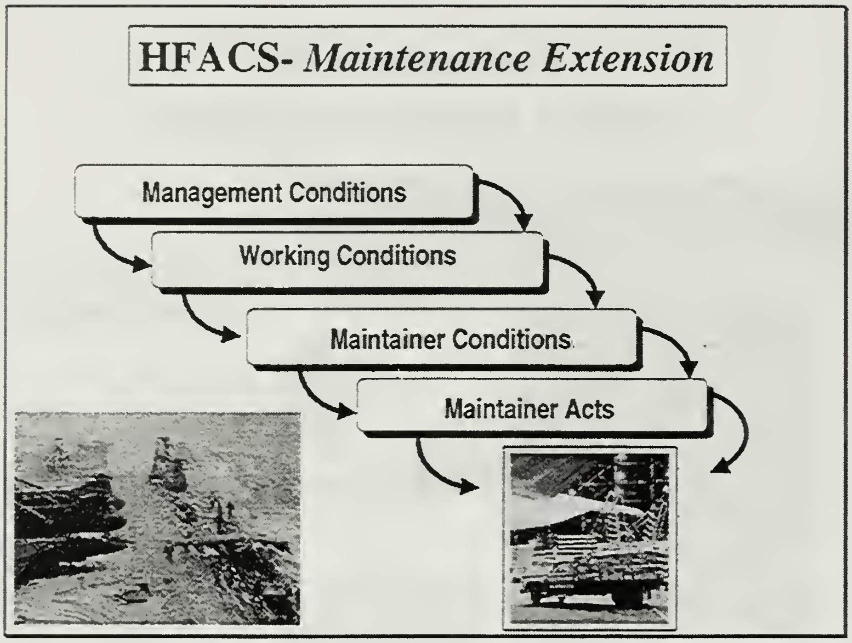
Best Practices Benchmarking

Command Safety Assessment

OK, so we must investigate all mishaps. Are there better or different methods of investigation? Has anything been overlooked?
Occasionally, an accident is so unique and overwhelming that it sends shock waves throughout the industry. These "watershed events" provide a change in focus and are major catalysts for change. One of the more famous "watershed events" was the 1996 Nashville, Tennessee F-14 mishap. This mishap had no material factors…it was a human error mishap.

Following this mishap, the Commander, Naval Air Forces Pacific (COMNAVAIRPAC) empanelled a Human Factors Quality Management Board (HFQMB) to identify human factors threats and develop intervention methods to combat them.
The HFQMB determined that Human Factors was the key to reducing the mishap rate to 1.0 (the desired 50% reduction per decade with current rates stagnate near 2.0)
The HFQMB adopted a three-prong approach to study human errors in mishaps:
Mishap data analysis to identify hazards and risks
Benchmarking (of other military services, NATO partners, private industry, etc.) to uncover best practices and find process improvements
Developing a Command Safety Assessment
The QMB's initial efforts were primarily directed at aircrew errors, but the QMB later directed a Human Factors in Maintenance and Material (HFAMM) Process Action Team (PAT) to address maintenance errors, as well.

Slide 8



HFACS- *Maintenance Extension*

Management Conditions

Working Conditions

Maintainer Conditions

Maintainer Acts

HFACS was developed to identify factors that relate to aircrew error. The Maintenance Extension (HFACS-ME) was added to analyze human error in maintenance related mishaps. So how does HFACS identify the factors specifically related to aviation maintenance accidents?

The "Maintenance Extension" taxonomy for HFACS was developed to further classify causal factors that contribute to maintenance related mishaps. This addition to HFACS consists of four broad human error categories:

Management Conditions (latent)
Working Conditions (latent)
Maintainer Conditions (latent)
Maintainer Acts (active)

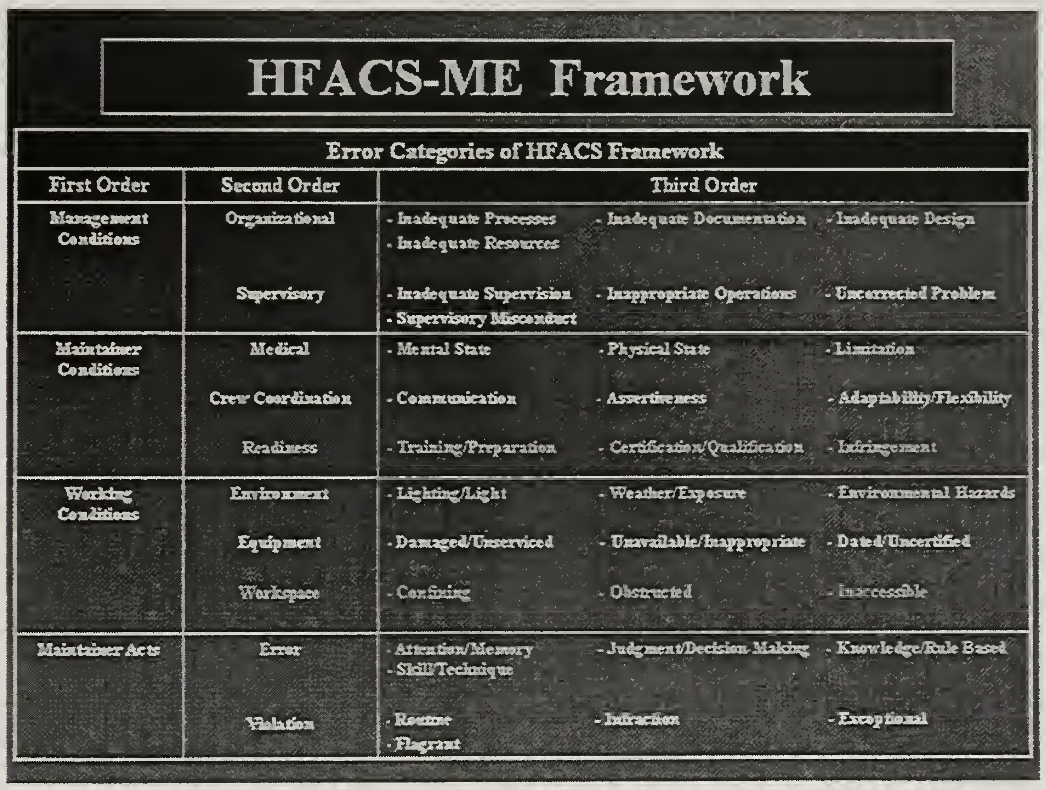
But does it work? YES! HFACS has been applied effectively to the analysis of previous Navy mishaps. Additional causal factors were identified, and more importantly, the classification or coding of these factors was incorporated into an already extensive database of accidents and incidents. Standardized coding allows identification of trends throughout the various accidents and will enable analysts to offer further prevention strategies.

Most important: This DOES NOT require a reinvestigation of the mishap. It can be accomplished, with minimal training, by investigators or analysts simply coding the narratives and causal factors that previously were reported.

Due to its success:

- HFACS has been adopted for inclusion into the Naval Aviation Safety Program (OPNAV 3750.6R)
- It has influenced policy changes to the Navy's Maintenance Program (4790 series)
- And is being used to further the effectiveness of Naval Aviation's methods of accident investigation, reporting, and database entry.

Slide 9



HFACS-ME Framework

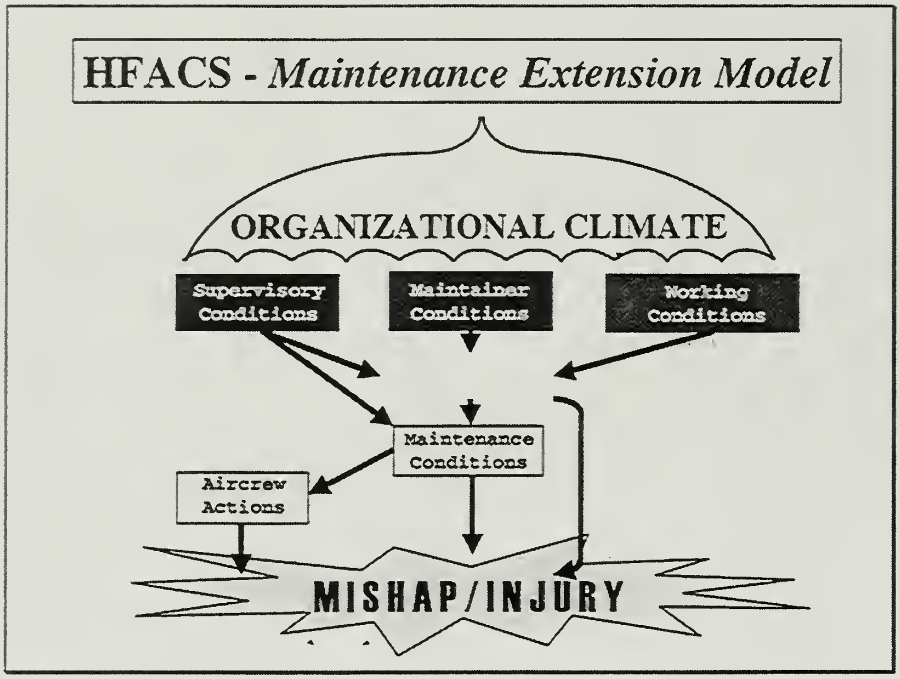
Error Categories of HFACS Framework				
First Order	Second Order	Third Order		
Management Conditions	Organizational	- Inadequate Processes - Inadequate Resources	- Inadequate Documentation	- Inadequate Design
	Supervisory	- Inadequate Supervision - Supervisory Misconduct	- Inappropriate Operations	- Uncorrected Problem
Maintainer Conditions	Medical	- Mental State	- Physical State	- Limitation
	Crew Coordination	- Communication	- Assertiveness	- Adaptability/Flexibility
	Readiness	- Training/Preparation	- Certification/Qualification	- Infringement
Working Conditions	Environment	- Lighting/Light	- Weather/Exposure	- Environmental Hazards
	Equipment	- Damaged/Unserviced	- Unavailable/Inappropriate	- Dated/Uncertified
	Workspace	- Confining	- Obstructed	- Inaccessible
Maintainer Acts	Error	- Attention/Memory - Skill/Technique	- Judgment/Decision Making	- Knowledge/Rule Based
	Violation	- Routine - Flagrant	- Infraction	- Exceptional

The HFACS-ME taxonomy also includes three orders of error: first, second, and third that reflect a macro to micro perspective.

The levels provide sufficient description to develop a searchable database and are useful for distinguishing supervisory areas of action. For example, a First Order category could be briefed at the Executive level, a Second Order at the Vice President/Senior Manager levels, and the Third Order can be corrected by Safety Officers and front line supervisors.

An Example: Maintainer Conditions (First Order), Readiness (Second Order), and Qualification/Certification (Third Order)

Slide 10



HFACS - *Maintenance Extension Model*

ORGANIZATIONAL CLIMATE

Supervisory Conditions

Maintainer Conditions

Working Conditions

Maintenance Conditions

Aircrew Actions

MISHAP/INJURY

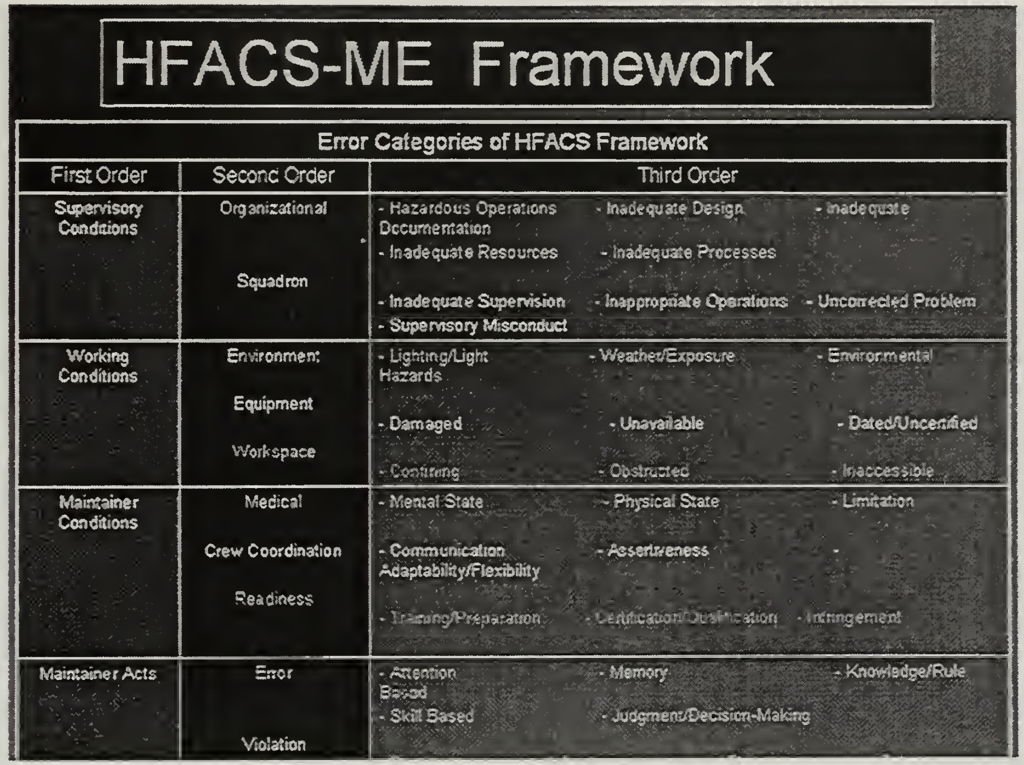
This model provides a realistic example of the interaction between the Error Categories.

Supervisory Conditions, **Maintainer Conditions**, and **Working Conditions** may INDEPENDENTLY or COLLECTIVELY affect the **Maintainers Actions**.
The **Unsafe Maintainer Act** which follows may either:
(1) Lead directly to a mishap or injury (Example: a maintainer runs a forklift into the side of an aircraft and damages it), or
(2) Become a latent **Maintenance Condition**, which the aircrew would have to deal with on take-off, in-flight, or on landing. (Example: an improperly rigged landing gear that collapses on touchdown or an over-torqued hydraulic line that fails in flight and causes a fire)

It is important to note that **Supervisory Conditions** related to design for maintainability, prescribed maintenance procedures, and standard maintenance operations could be inadequate and also lead directly to a **Maintenance Condition.**

Please note that this model utilizes only the First Order Error Categories (again, shown in red). So how does the Second Order Error Categories affect this relationship? (quickly go to next slide)

Slide 11

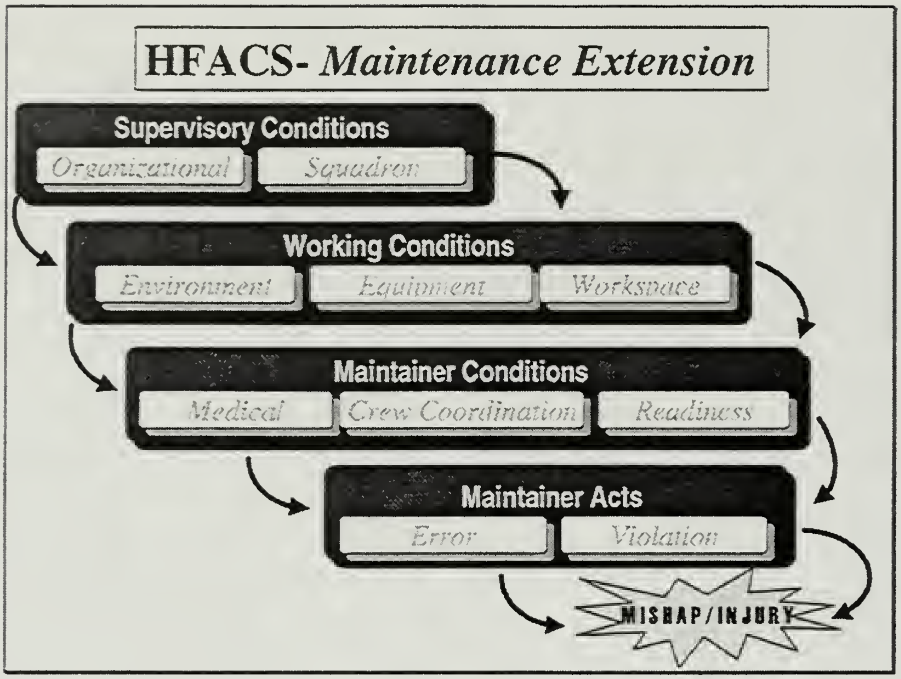


HFACS-ME Framework

Error Categories of HFACS Framework		
First Order	Second Order	Third Order
Supervisory Conditions	Organizational	- Hazardous Operations - Inadequate Design - Inadequate Documentation - Inadequate Resources - Inadequate Processes
	Squadron	- Inadequate Supervision - Inappropriate Operations - Uncorrected Problem - Supervisory Misconduct
Working Conditions	Environment	- Lighting/Light - Weather/Exposure - Environmental Hazards
	Equipment	- Damaged - Unavailable - Dated/Uncertified
	Workspace	- Confining - Obstructed - Inaccessible
Maintainer Conditions	Medical	- Mental State - Physical State - Limitation
	Crew Coordination	- Communication - Assertiveness - Adaptability/Flexibility
	Readiness	- Training/Preparation - Certification/Qualification - Infringement
Maintainer Acts	Error	- Attention - Memory - Knowledge/Rule Based - Skill Based - Judgment/Decision-Making
	Violation	

The Second Order of Error Categories (shown in Blue) is simply a further breakdown, or description, of the First Order Error Category (so additional relationship models are not necessary). If we look back a couple of slides…(quickly go to next slide)…

Slide 12



HFACS- *Maintenance Extension*

Supervisory Conditions

Organizational *Squadron*

Working Conditions

Environment *Equipment* *Workspace*

Maintainer Conditions

Medical *Crew Coordination* *Readiness*

Maintainer Acts

Error *Violation*

MISHAP/INJURY

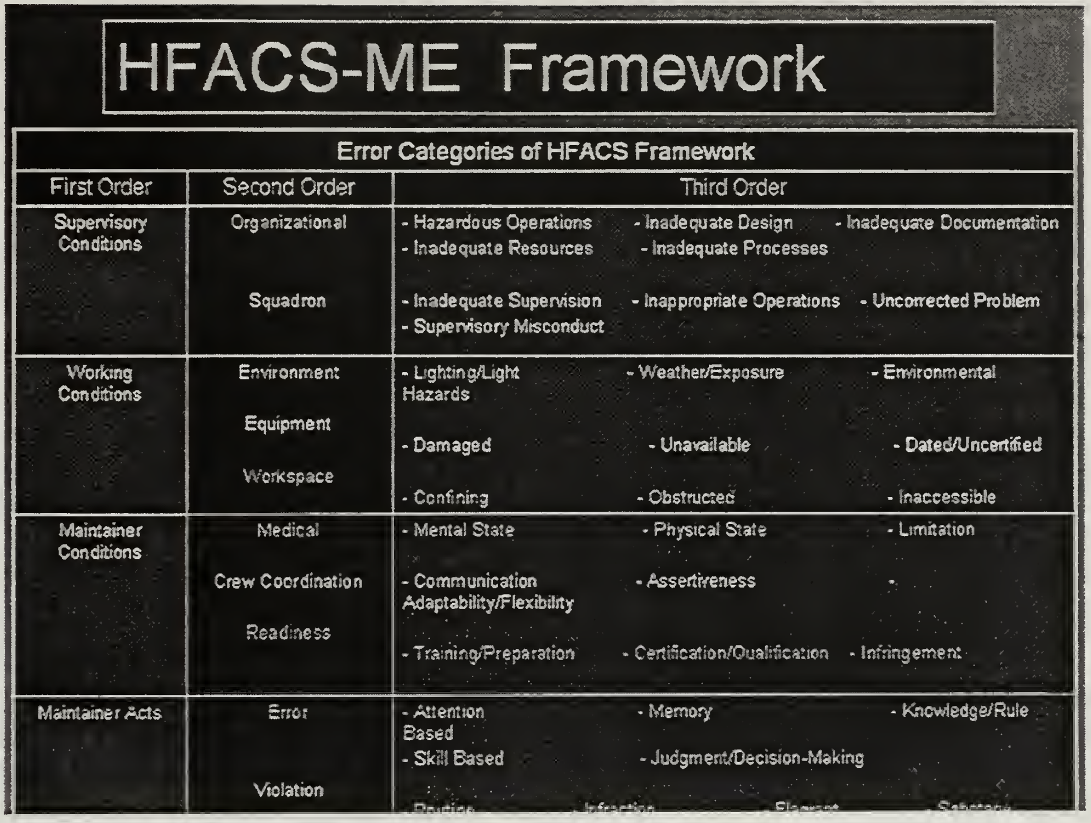
…the incorporation of the Second Order Error Categories would look like this.

Supervisory Conditions are established at the **Organizational** levels (outside your command) or at your **Squadron** level.
Working Conditions that affect one or more maintainers include the **Environment**, **Equipment**, and **Workspace** limitations.
Maintainer Conditions directly impact an individual maintainer and may include **Medical**, **Crew Coordination**, or **Readiness** factors.
Maintainer Acts can either be **Errors** or **Violations**.

(NOTE: Multiple Error Categories may be factors in mishaps. For example, both Organizational and Squadron practices may combine to form Supervisory Conditions that lead to mishaps, or a combination of Equipment and Workspace conditions may promote an unsafe Working Condition.)

Now, as you probably surmised, the Third Order Error Categories are simply a further breakdown of the Second Order Error Categories shown on this slide.

Slide 13



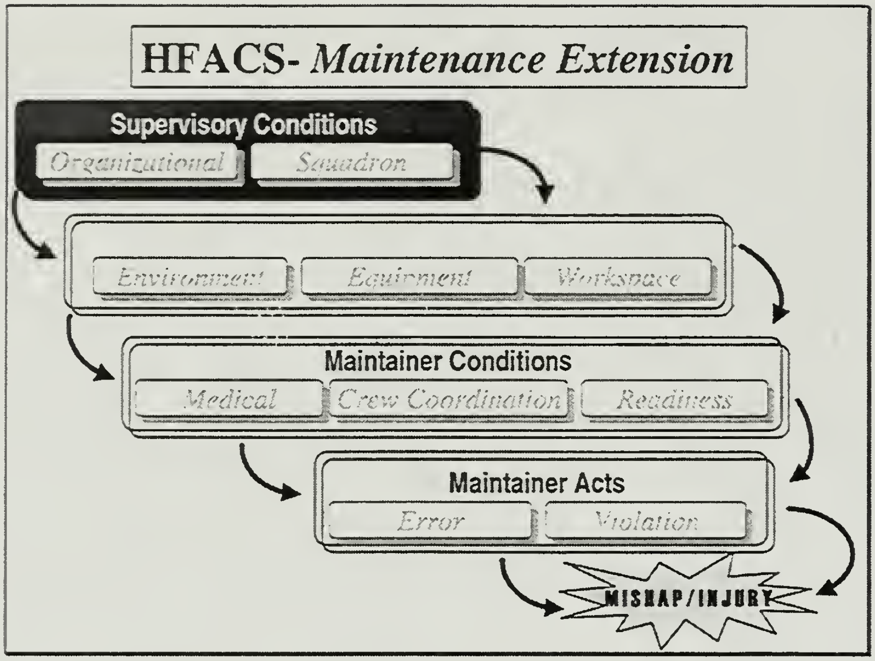
HFACS-ME Framework

Error Categories of HFACS Framework		
First Order	Second Order	Third Order
Supervisory Conditions	Organizational	- Hazardous Operations - Inadequate Design - Inadequate Documentation - Inadequate Resources - Inadequate Processes
	Squadron	- Inadequate Supervision - Inappropriate Operations - Uncorrected Problem - Supervisory Misconduct
Working Conditions	Environment	- Lighting/Light Hazards - Weather/Exposure - Environmental
	Equipment	- Damaged - Unavailable - Dated/Uncertified
	Workspace	- Confining - Obstructed - Inaccessible
Maintainer Conditions	Medical	- Mental State - Physical State - Limitation
	Crew Coordination	- Communication - Assertiveness - Adaptability/Flexibility
	Readiness	- Training/Preparation - Certification/Qualification - Infringement
Maintainer Acts	Error	- Attention - Memory - Knowledge/Rule Based - Skill Based - Judgment/Decision-Making
	Violation	

Here again, are the Third Order Error Categories (now displayed in Green).

The most effective way to define and display the relationship of First, Second, and Third error categories is to examine each First Order Category independently. (quickly go to next slide)

Slide 14



HFACS- *Maintenance Extension*

Supervisory Conditions

Organizational *Squadron*

Environment *Equipment* *Workspace*

Maintainer Conditions

Medical *Crew Coordination* *Readiness*

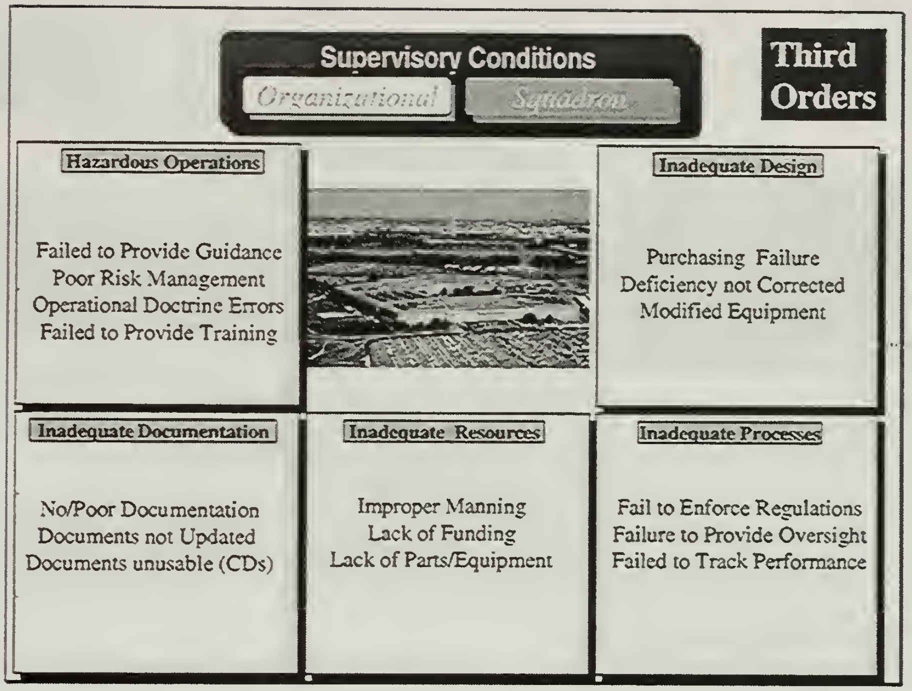
Maintainer Acts

Error *Violation*

MISHAP/INJURY

We will begin by examining the Supervisory Conditions First Order. (quickly go to next slide)

Slide 15



Supervisory Conditions

Organizational Squadron

Third Orders

Hazardous Operations

Failed to Provide Guidance
Poor Risk Management
Operational Doctrine Errors
Failed to Provide Training

Inadequate Design

Purchasing Failure
Deficiency not Corrected
Modified Equipment

Inadequate Documentation

No/Poor Documentation
Documents not Updated
Documents unusable (CDs)

Inadequate Resources

Improper Manning
Lack of Funding
Lack of Parts/Equipment

Inadequate Processes

Fail to Enforce Regulations
Failure to Provide Oversight
Failed to Track Performance

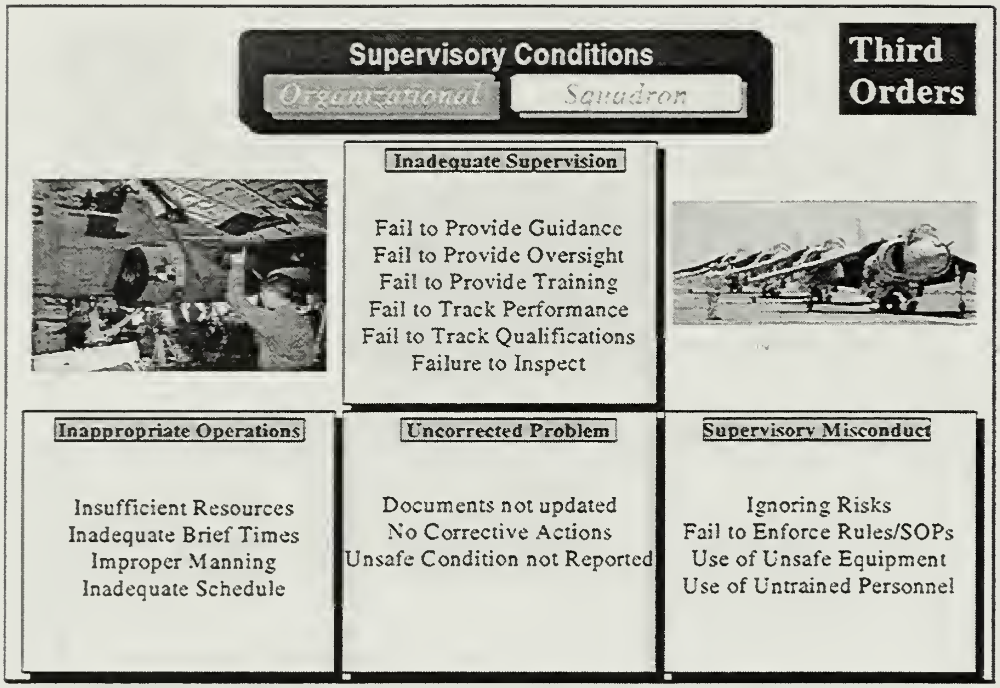
Under Supervisory Conditions, we have both Organizational and Squadron Second Order Error Categories.
We will start with the Organizational Category.

(Facilitator note: Read each term and its example below and then mention some of the additional examples listed in each box on the slide. Encourage discussion from students)

Under the Organizational Second Order, we have the following Third Order Error Categories:
Hazardous Operations An engine that falls off of a stand during a change out evolution due to an unforeseen hazard of a high seas state
Inadequate Design The poor layout of system components that do not permit direct observation of maintenance being performed
Inadequate Documentation A manual omits a step in a maintenance procedure, such as leaving out an o-ring that causes a fuel leak
Inadequate Resources Insufficient funding, manpower, tools, parts and equipment to perform maintenance effectively and safely
Inadequate Processes Limitations in teamwork, communication, and directives within and between organizations

(NOTE: The descriptions given, and the examples shown on the slide, are just that . . . examples. The purpose of this presentation is to establish a knowledge and understanding of the HFACS-ME Categories, not restrict their use to only a handful of scenarios.)

Slide 16



Supervisory Conditions

Organizational

Squadron

Third Orders

Inadequate Supervision

Fail to Provide Guidance
Fail to Provide Oversight
Fail to Provide Training
Fail to Track Performance
Fail to Track Qualifications
Failure to Inspect

Inappropriate Operations

Insufficient Resources
Inadequate Brief Times
Improper Manning
Inadequate Schedule

Uncorrected Problem

Documents not updated
No Corrective Actions
Unsafe Condition not Reported

Supervisory Misconduct

Ignoring Risks
Fail to Enforce Rules/SOPs
Use of Unsafe Equipment
Use of Untrained Personnel

And under the Squadron Second Order Supervisory Condition, we have these Third Order Error Categories:

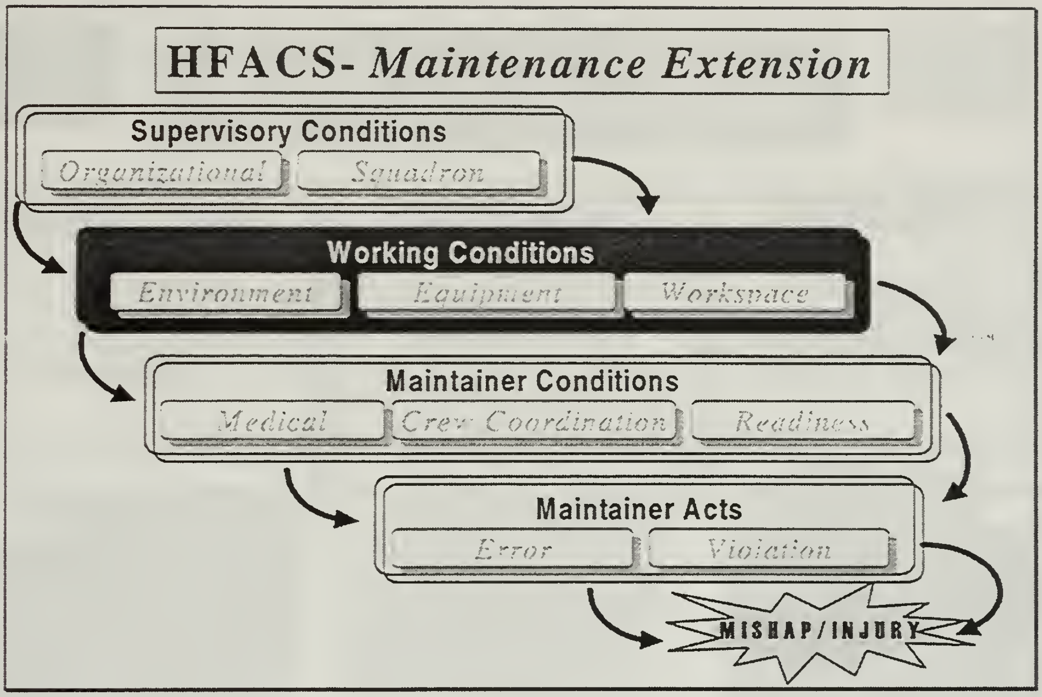
Inadequate Supervision A supervisor who does not ensure that maintenance personnel are wearing required personal protective gear

Inappropriate Operations A supervisor who directs a maintainer to perform a task without considering risks, such as driving a truck through a hangar

Uncorrected Problem A supervisor who neglects to correct maintainers who routinely bend the rules when they perform a common task

Supervisory Misconduct A supervisor who willfully orders a maintainer to wash an aircraft without proper safety gear

Slide 17



HFACS- *Maintenance Extension*

Supervisory Conditions

Organizational
Squadron

Working Conditions

Environment
Equipment
Workspace

Maintainer Conditions

Medical
Crew Coordination
Readiness

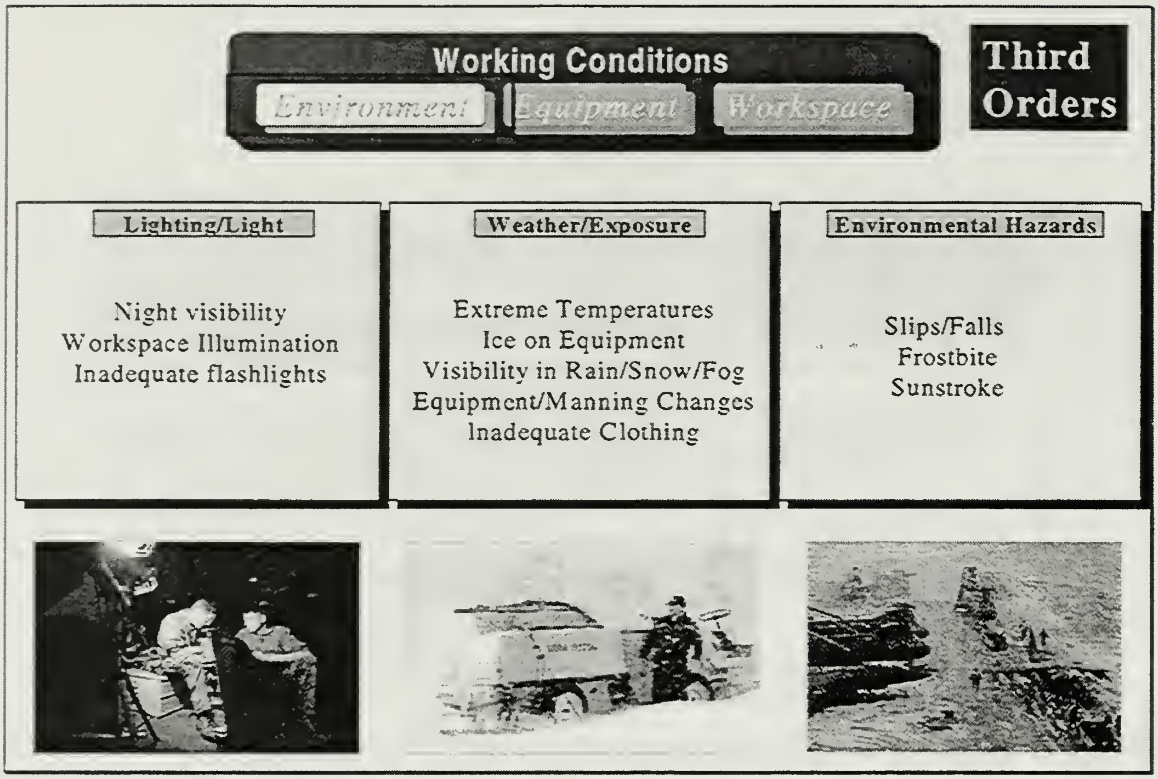
Maintainer Acts

Error
Violation

MISHAP/INJURY

Let us now examine the Working Conditions First Order Error Category breakdown.
(Again advise students to follow along with their copy of the HFACS-ME Framework slide).
(quickly go to next slide)

Slide 18



Working Conditions

Environment Equipment Workspace

Third Orders

Lighting/Light

Night visibility
Workspace Illumination
Inadequate flashlights

Weather/Exposure

Extreme Temperatures
Ice on Equipment
Visibility in Rain/Snow/Fog
Equipment/Manning Changes
Inadequate Clothing

Environmental Hazards

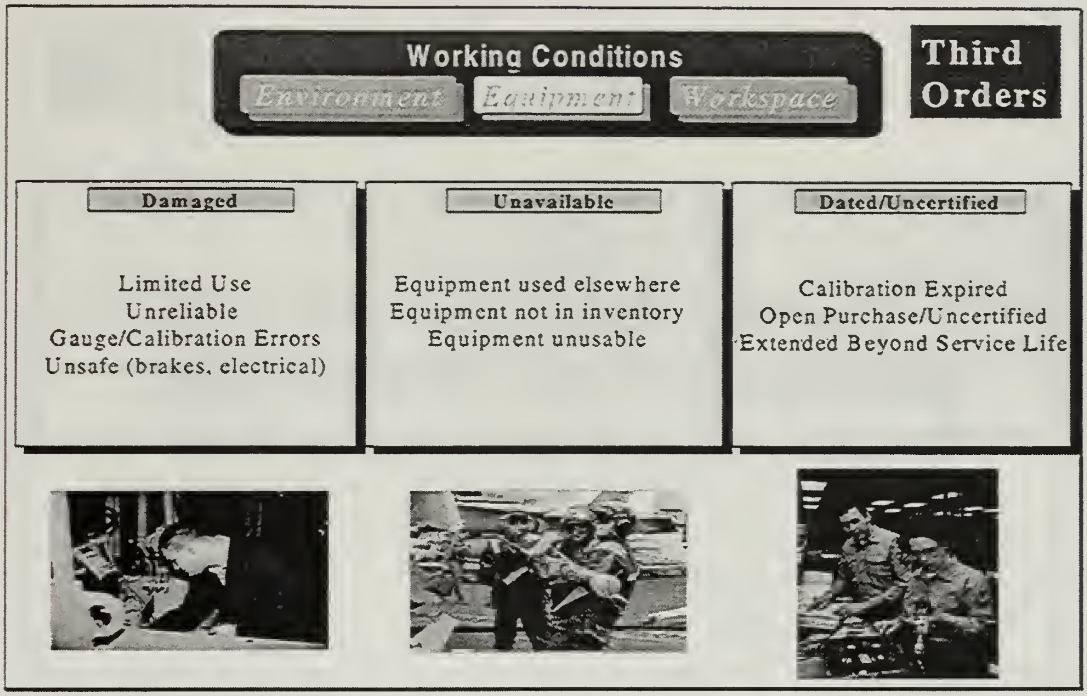
Slips/Falls
Frostbite
Sunstroke

Working Conditions have Second Order Error Categories of **Environment, Equipment, and Workspace factors.**

The Environment Second Order can be further broken down into the following Third Orders:
Lighting/Light A maintainer who is working at night on the flight line does not see a tool he left behind
Weather/Exposure A maintainer who is securing an aircraft in a driving rain fails to properly attach the chains
Environmental Hazards A maintainer who is working on a pitching deck falls from the aircraft.

(Note: Environmental Factors are often not adequately reported.)

Slide 19



Working Conditions

Environment Equipment Workspace

Third Orders

Damaged

Limited Use
Unreliable
Gauge/Calibration Errors
Unsafe (brakes, electrical)

Unavailable

Equipment used elsewhere
Equipment not in inventory
Equipment unusable

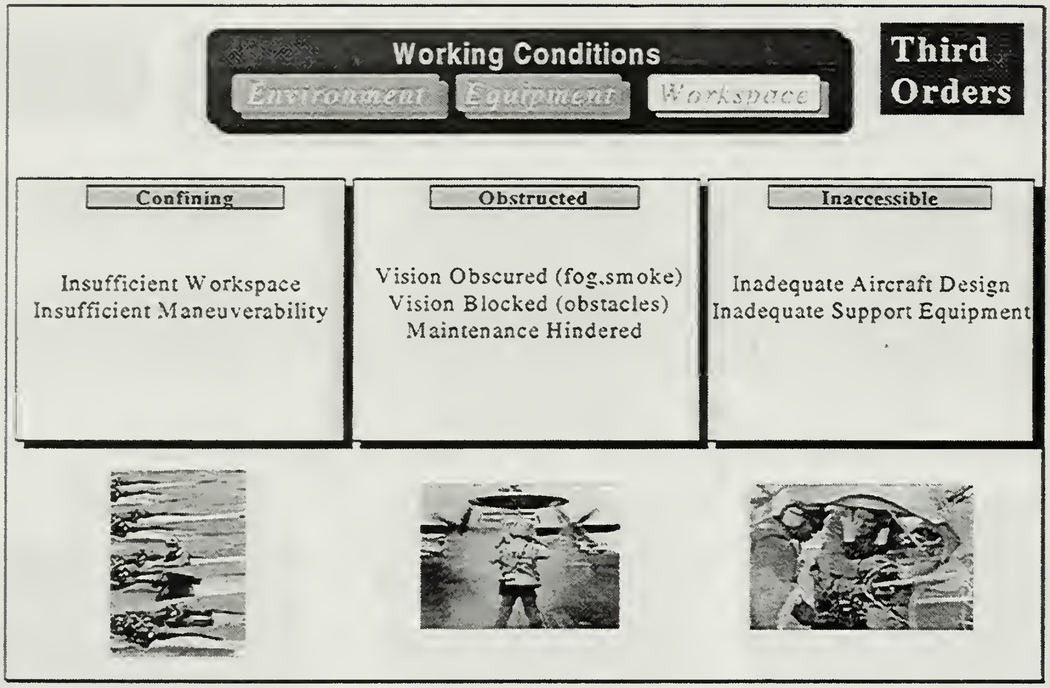
Dated/Uncertified

Calibration Expired
Open Purchase/Uncertified
Extended Beyond Service Life

Equipment Third Orders are:
Damaged A maintainer who is using a defective test set does not pre-check it before troubleshooting
Unavailable A maintainer who starts working on landing gear without a jack because all are being used
Dated/Uncertified A maintainer who uses an old manual because a CD-ROM reader is not available.

(Note: Tools and Equipment Factors are also not adequately reported.)

Slide 20


Environment
Equipment
Workspace

Working Conditions

Third Orders

Confining

Insufficient Workspace
Insufficient Maneuverability

Obstructed

Vision Obscured (fog,smoke)
Vision Blocked (obstacles)
Maintenance Hindered

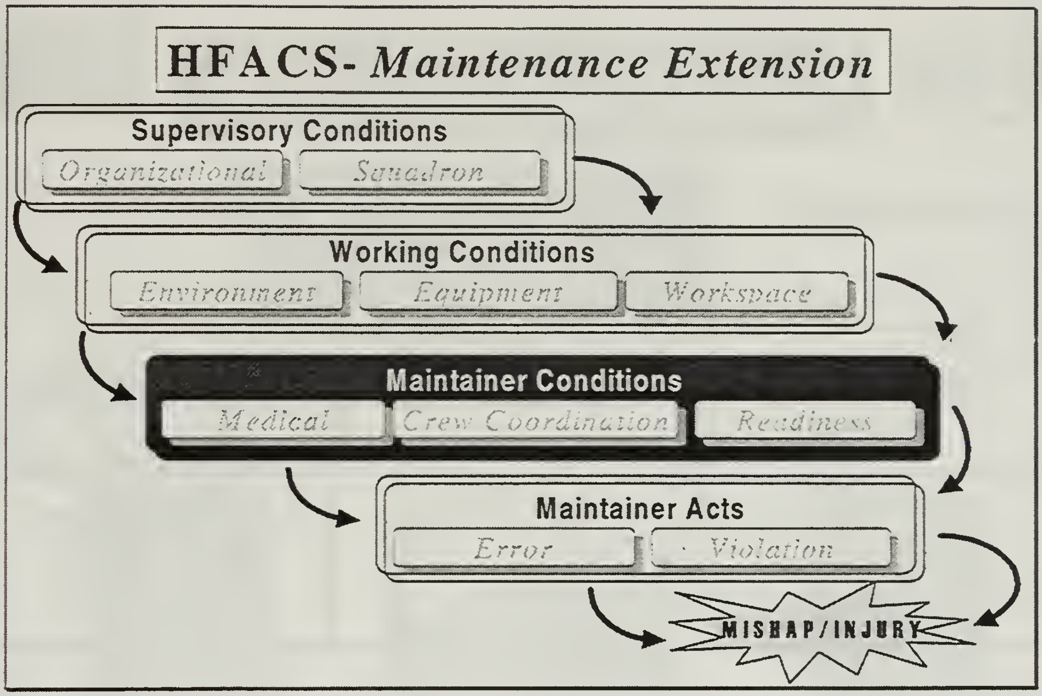
Inaccessible

Inadequate Aircraft Design
Inadequate Support Equipment

And finally, Workspace factors can be separated into these Third Order Error Categories:
Confining A maintainer who is working in a hangar bay cannot properly position the maintenance stand
Obstructed A maintainer who is spotting an aircraft with his view obscured by catapult steam
Inaccessible A maintainer who is unable to perform a corrosion inspection that is beyond his reach.

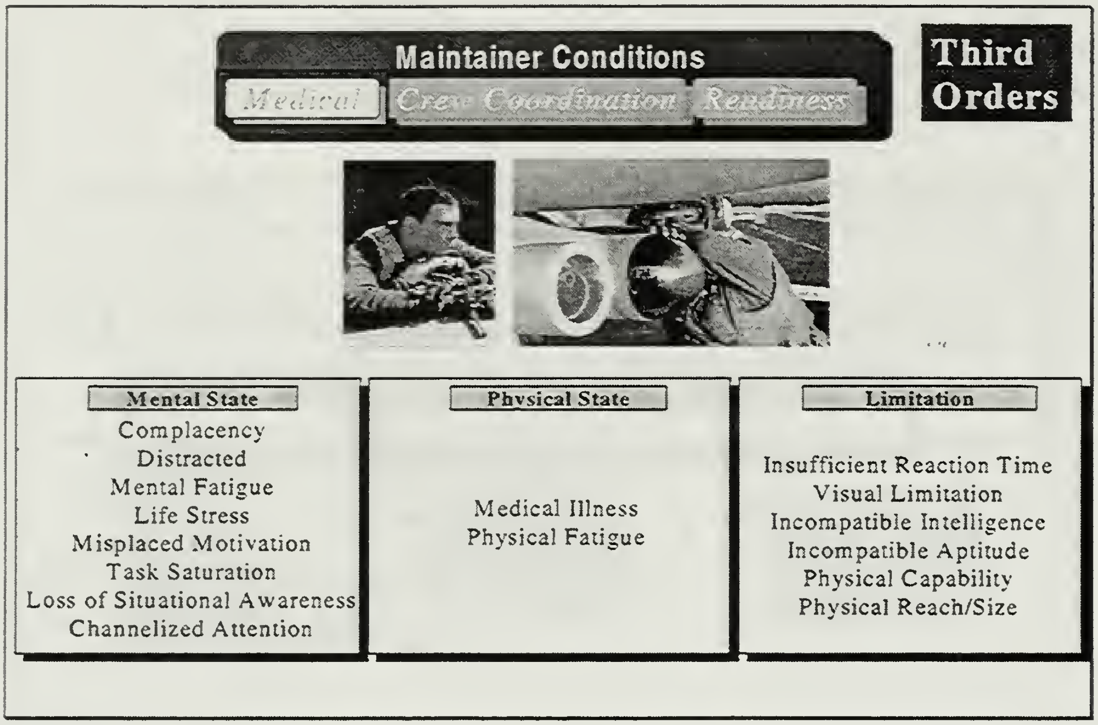
(Note: Workspace factors are also not adequately reported.)

Slide 21



Maintainer Conditions, the conditions that uniquely affect individual maintainers, are separated into Medical, Crew Coordination and Readiness Categories. (quickly go to next slide)

Slide 22



Maintainer Conditions

Medical | Crew Coordination | Readiness

Third Orders

Mental State

Complacency
Distracted
Mental Fatigue
Life Stress
Misplaced Motivation
Task Saturation
Loss of Situational Awareness
Channelized Attention

Physical State

Medical Illness
Physical Fatigue

Limitation

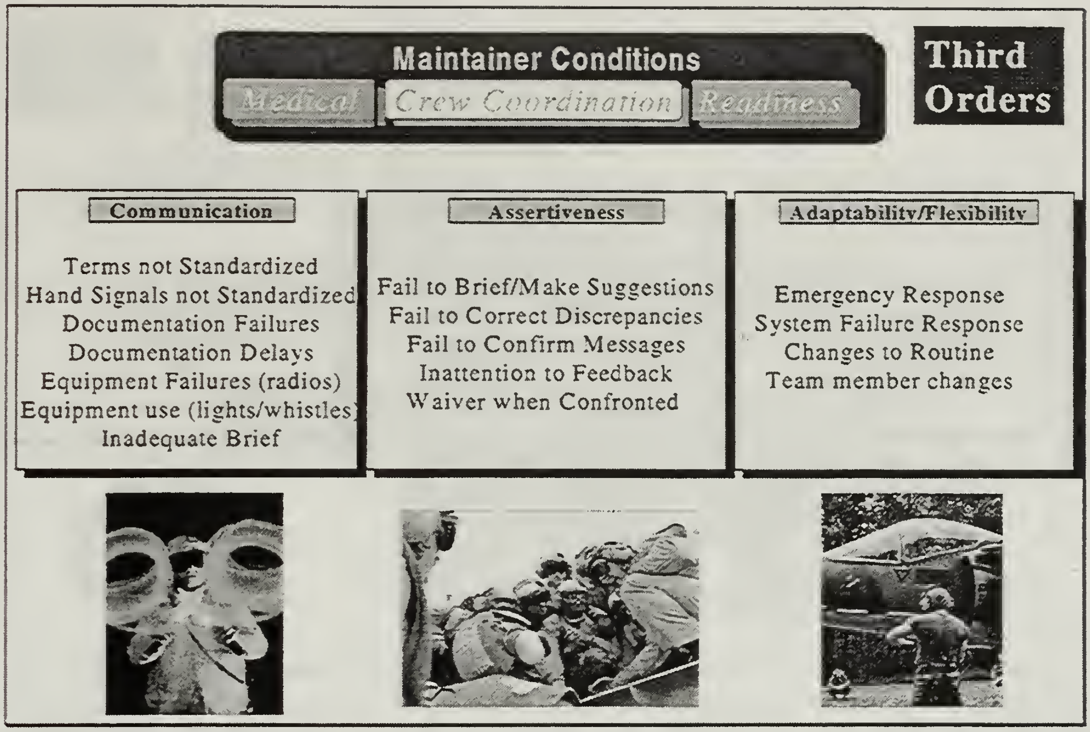
Insufficient Reaction Time
Visual Limitation
Incompatible Intelligence
Incompatible Aptitude
Physical Capability
Physical Reach/Size

The Medical Third Orders are based on an individuals mental and physical abilities (and limitations) to perform a task at a certain time.

They include:
Mental State A maintainer who has a marital problem and cannot focus on a maintenance action
Physical State A maintainer who worked for 20 hours straight and suffers from fatigue
Limitation (Physical) A maintainer who is short cannot visually inspect an aircraft before it is launched

(Note: Medical Factors are not reported adequately)

Slide 23



Maintainer Conditions

Medical | Crew Coordination | Readiness

Third Orders

Communication

- Terms not Standardized
- Hand Signals not Standardized
- Documentation Failures
- Documentation Delays
- Equipment Failures (radios)
- Equipment use (lights/whistles)
- Inadequate Brief

Assertiveness

- Fail to Brief/Make Suggestions
- Fail to Correct Discrepancies
- Fail to Confirm Messages
- Inattention to Feedback
- Waiver when Confronted

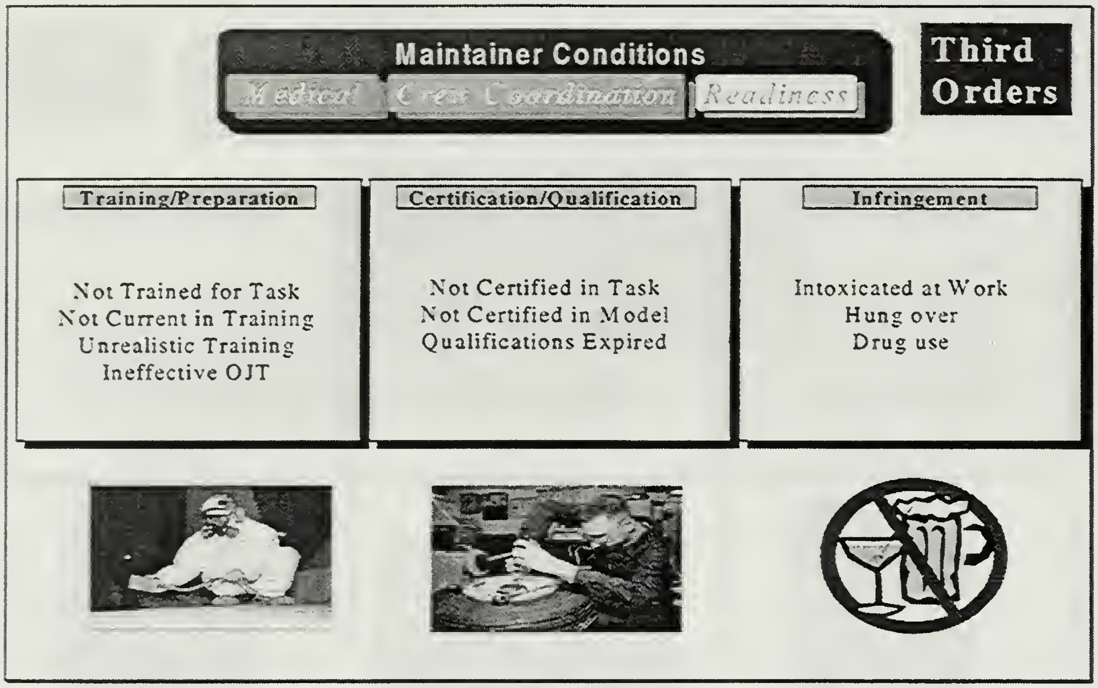
Adaptability/Flexibility

- Emergency Response
- System Failure Response
- Changes to Routine
- Team member changes

Crew Coordination factors include problems in:

Communication A maintainer who leads a taxiing aircraft into another due to improper hand signals.
Assertiveness A maintainer who performs a task, not in accordance with standard procedures, because the maintainer was overly submissive to a superior.
Adaptability/Flexibility A maintainer who downplays a downing discrepancy to meet the flight schedule.

Slide 24



Maintainer Conditions

Medical | Crew Coordination | Readiness

Third Orders

Training/Preparation	Certification/Qualification	Infringement
Not Trained for Task Not Current in Training Unrealistic Training Ineffective OJT	Not Certified in Task Not Certified in Model Qualifications Expired	Intoxicated at Work Hung over Drug use

And the last Maintainer Conditions category to discuss is Readiness. Its Third Orders involve:

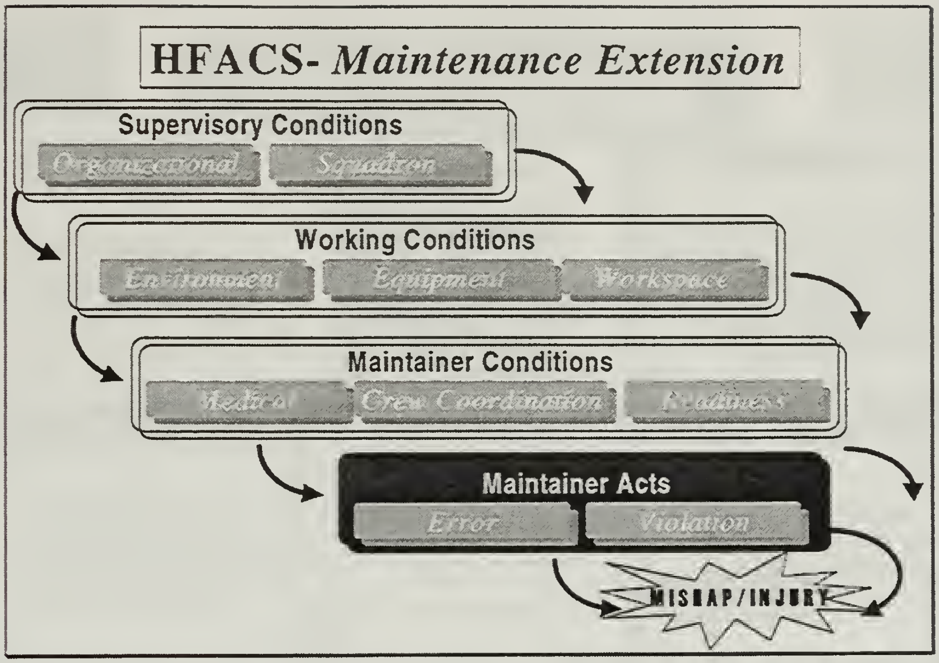
Training/Preparation A maintainer who is working on an aircraft skipped the requisite OJT evolution

Certification/Qualification A maintainer who engages in a procedure that he or she has not been qualified to perform

Infringement A maintainer who is intoxicated on the job.

(Note: Readiness Factors are also not reported adequately.)

Slide 25



HFACS- *Maintenance Extension*

Supervisory Conditions
- Organizational
- Squadron

Working Conditions
- Environment
- Equipment
- Workspace

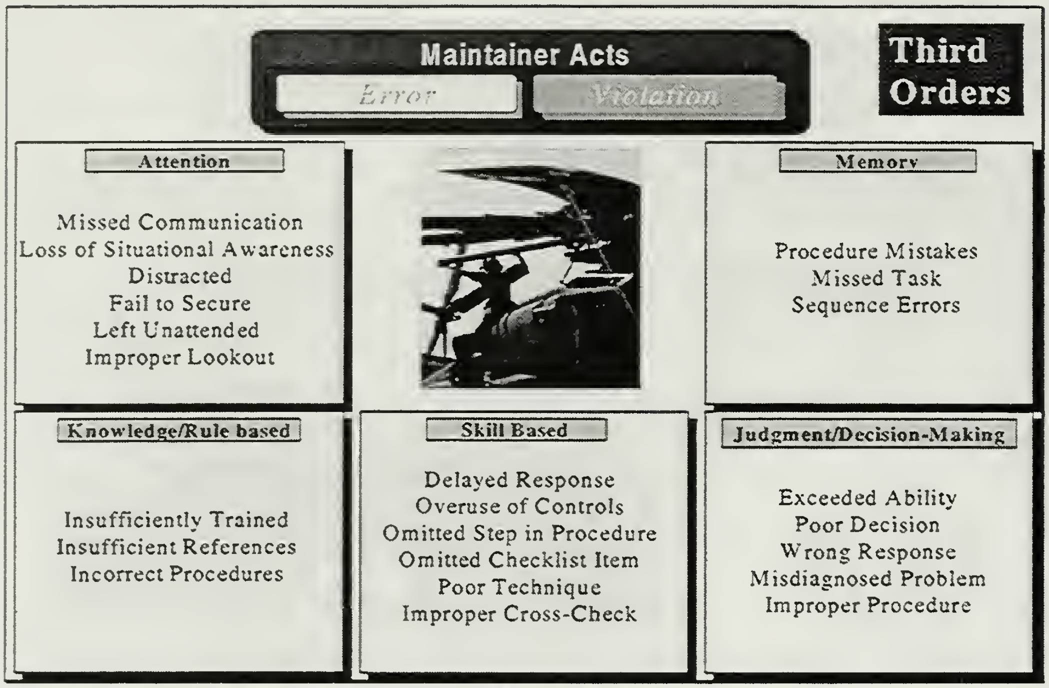
Maintainer Conditions
- Medical
- Crew Coordination
- Readiness

Maintainer Acts
- Error
- Violation

MISHAP/INJURY

The final category is **Maintainer Acts**, which include **Errors** (mistakes) and **Violations** (willful acts). (quickly go to next slide)

Slide 26



Maintainer Acts

Error

Violation

Third Orders

Attention

Missed Communication
Loss of Situational Awareness
Distracted
Fail to Secure
Left Unattended
Improper Lookout

Memory

Procedure Mistakes
Missed Task
Sequence Errors

Knowledge/Rule based

Insufficiently Trained
Insufficient References
Incorrect Procedures

Skill Based

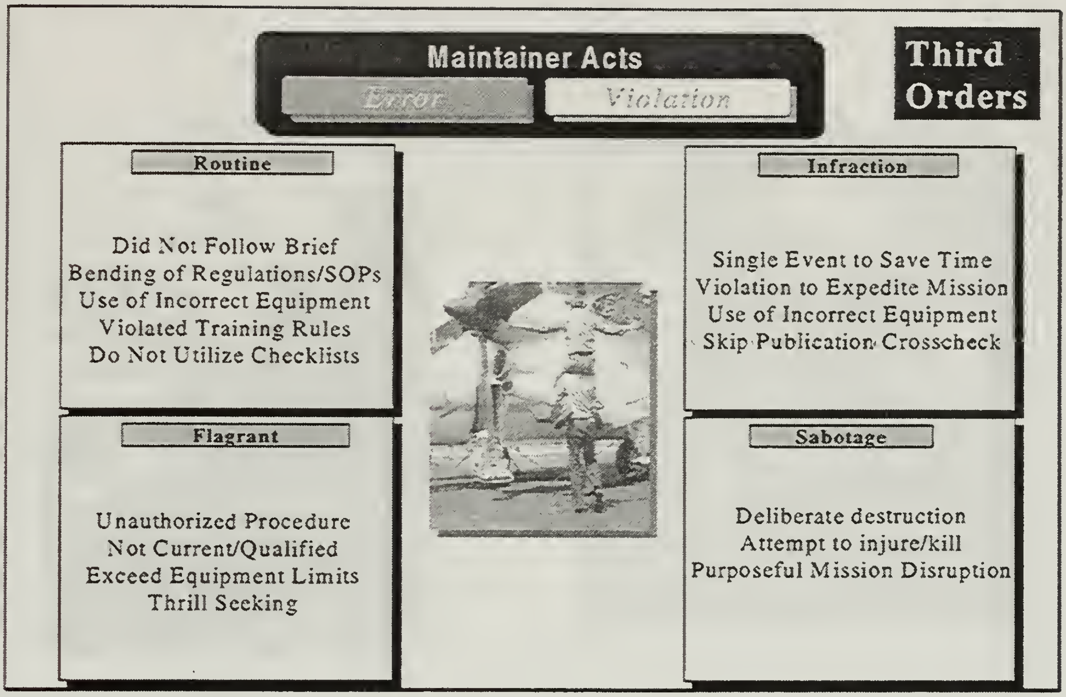
Delayed Response
Overuse of Controls
Omitted Step in Procedure
Omitted Checklist Item
Poor Technique
Improper Cross-Check

Judgment/Decision-Making

Exceeded Ability
Poor Decision
Wrong Response
Misdiagnosed Problem
Improper Procedure

Maintainer Errors are of the following Third Order types:
Attention A maintainer who misses a hand signal and backs a forklift into an aircraft
Memory A maintainer who is very familiar with a procedure may reverse steps in a sequence
Knowledge/Rule Based A maintainer who inflates an aircraft tire to a pressure required by a different aircraft
Skill Based A maintainer who roughly handles a delicate engine valve will cause undue damage
Judgment/Decision-Making A maintainer who fails to make appropriate decisions due to limited information, inadequate preparation, or perceived pressure to perform

Slide 27



Maintainer Acts

Error

Violation

Third Orders

Routine

Did Not Follow Brief
Bending of Regulations/SOPs
Use of Incorrect Equipment
Violated Training Rules
Do Not Utilize Checklists

Flagrant

Unauthorized Procedure
Not Current/Qualified
Exceed Equipment Limits
Thrill Seeking

Infraction

Single Event to Save Time
Violation to Expedite Mission
Use of Incorrect Equipment
Skip Publication Crosscheck

Sabotage

Deliberate destruction
Attempt to injure/kill
Purposeful Mission Disruption

There are also several types of Maintainer Violations. Their Third Order category is based upon frequency, intent, and supervisory involvement.

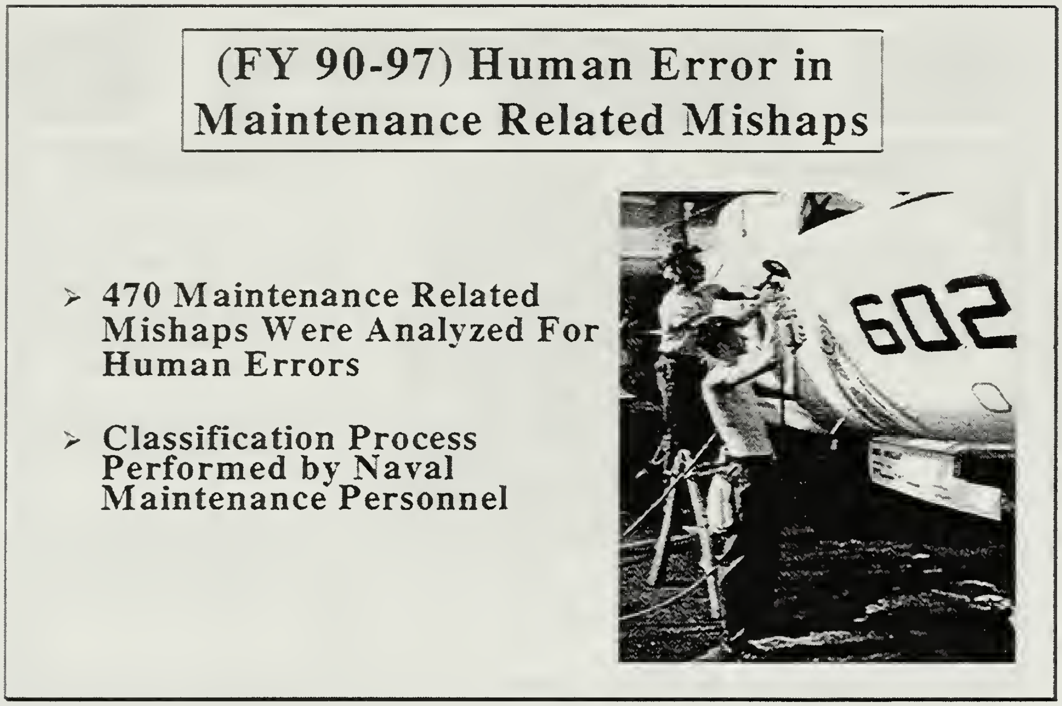
Routine A maintainer who engages in practices, condoned by management, that bend the rules

Infraction A maintainer who strays from accepted procedures to save time, bending a rule

Flagrant A maintainer who willfully breaks standing rules disregarding the consequences

Sabotage A maintainer who performs a criminal act to destroy equipment or endanger the lives of others

Slide 28

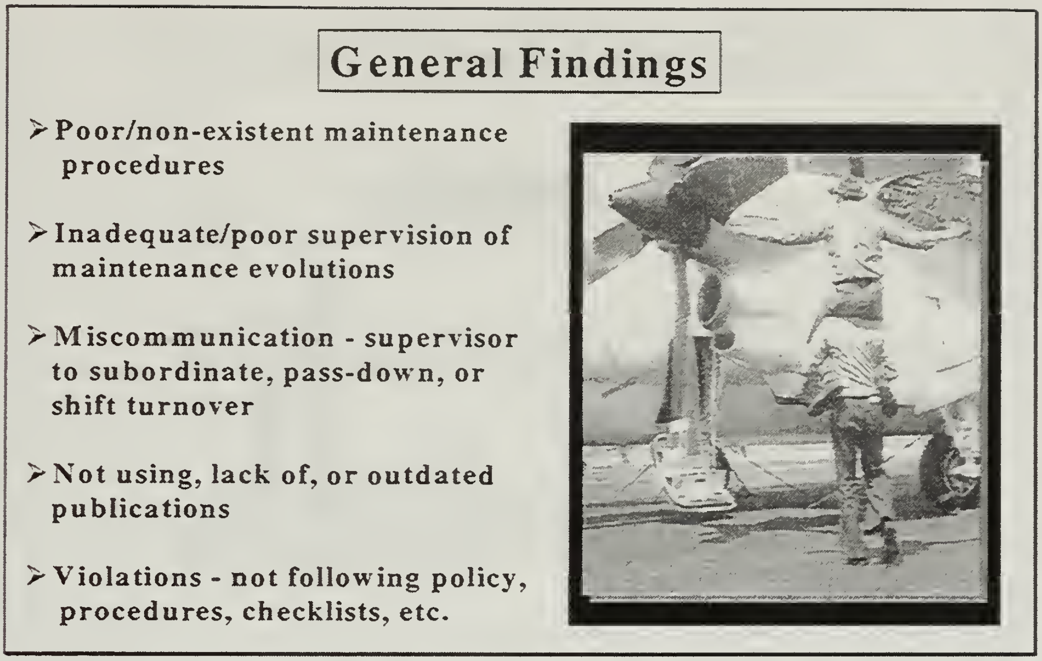


(FY 90-97) Human Error in Maintenance Related Mishaps

- 470 Maintenance Related Mishaps Were Analyzed For Human Errors
- Classification Process Performed by Naval Maintenance Personnel

HFACS, as previously stated, has been used effectively within the Navy. Without reopening an investigation, HFACS was applied to existing Mishap Investigation Reports.
(go to next slide for general findings).

Slide 29

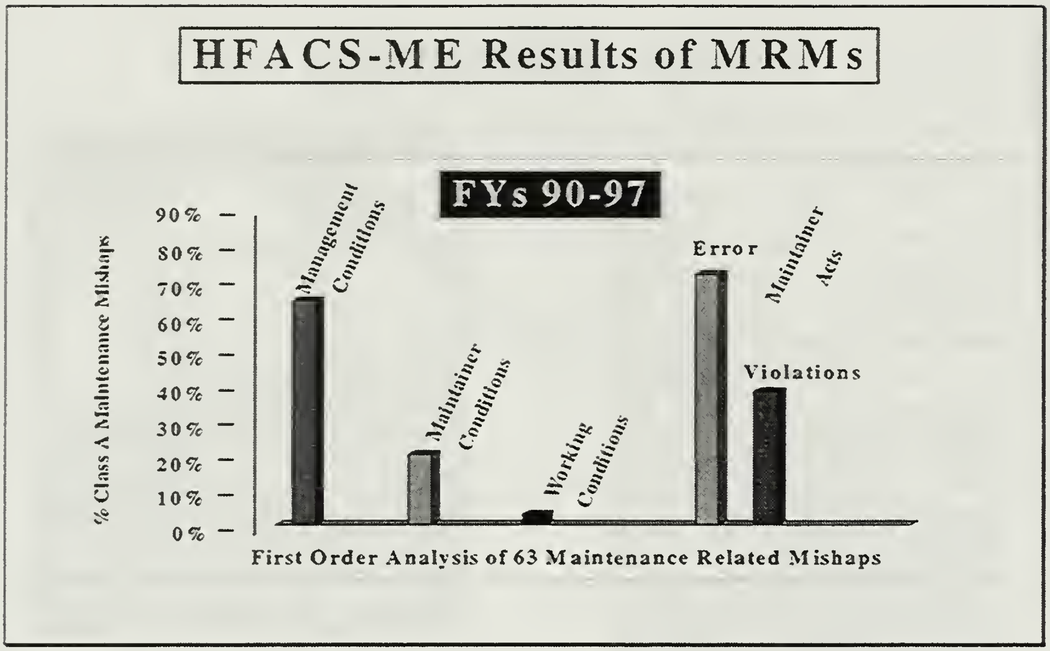


General Findings

- ➢ Poor/non-existent maintenance procedures
- ➢ Inadequate/poor supervision of maintenance evolutions
- ➢ Miscommunication - supervisor to subordinate, pass-down, or shift turnover
- ➢ Not using, lack of, or outdated publications
- ➢ Violations - not following policy, procedures, checklists, etc.

This slide shows the general findings of the analysis. I'm sure we are all familiar with these latent conditions. Let us now look at another study of 63 Class A mishaps between FYs 90-97. (go to next slide)

Slide 30



HFACS-ME Results of MRMs

HFACS ANALYSIS OF Class a FYs 90-97 Maintenance Related Mishaps (MRMs).

During FYs 90-97 there was a total of 63 Class A Mishaps. of which 61 were Flight, 0 were Flight Related, and 2 were Aircraft Ground. Two Navy Maintenance Officers and two Navy Chiefs used the HFACS Maintenance Extension to classify the human factors causes reported in these mishaps. They discovered the following profile of human errors:

Management Conditions - 67% of all Naval Aviation Class A MRMs reported Squadron Supervisory Conditions, whereas 21% had Unforeseen Supervisory Conditions (not shown).

Maintainer Conditions - 21% of all Naval Class A MRMs reported Medical, CRM, or Readiness Maintainer Conditions. ***Note: Maintainer Conditions were under reported, more are likely present and have an effect.***

Working Conditions - 3% of all Naval Class A MRMs reported Environment, Equipment, or Workspace Working Conditions. ***Note: Workspace Conditions were under reported, more are likely present and have an effect.***

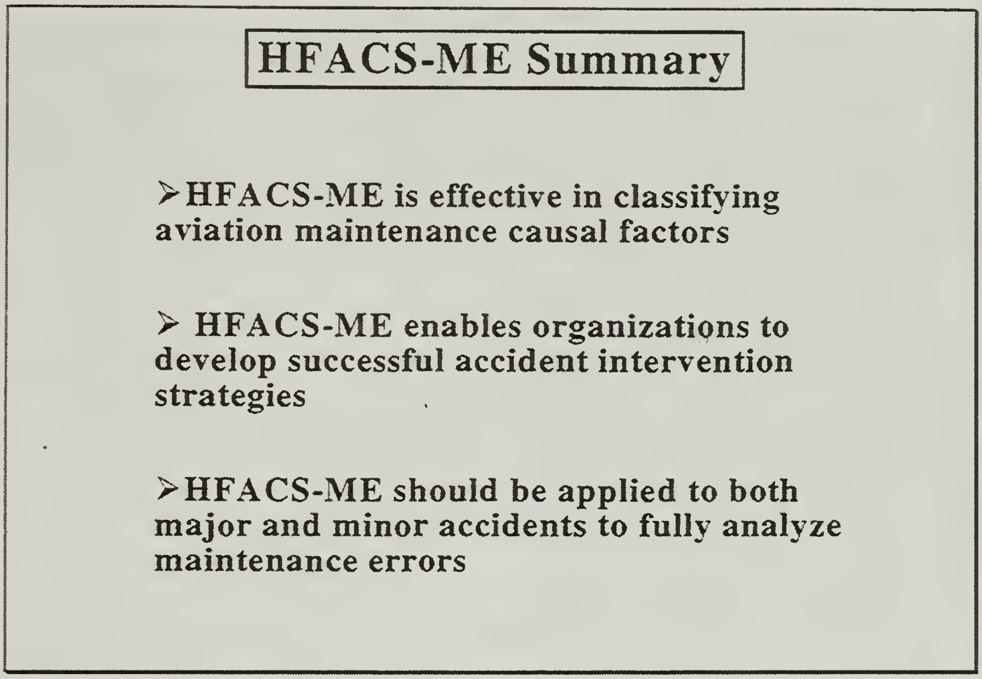
Maintainer Acts - 75% of all Naval Aviation Class A MRMs reported Maintainer Errors, whereas 40% had Maintainer Violations.

Clearly, latent conditions in the form of Supervisory, Maintainer, and Workspace factors are present that can impact maintainers in the performance of their jobs. However, many Maintainer and Workspace Conditions are not reported due to the reporting system in place, perceptions of accident causation, or culture/climate issues. Specifically, inadequate supervision of maintenance evolutions, not ensuring personnel are trained and/or qualified, not enforcing rules, and poor communication characterize the majority of latent Supervisory Conditions. Poor pass down, coordination, and communication; non-use or lack of publications, policies, and procedures; and fatigue comprise most latent Maintainer Conditions. Finally, most Maintainer Errors reflect a lack of training, experience, and skill, whereas Maintainer Violations consist of routine non-compliance with standard procedures and practices, and infractions, bending the rules in order to meet mission requirements and the flight schedule.

Conclusions

HFACS-ME was effective in capturing the nature of and relationships among latent conditions and active failures present in Class A MRMs. The insights gained provide a solid perspective for the development of potential intervention strategies. The major mishaps analyzed were primarily FMs, meaning that many imposed in-flight Maintenance Conditions on aircrew. During FYs 90-97 there were almost 500 MRMs in Naval Aviation, many of which were of lesser severity and were either Flight Related or Aircraft Ground Mishaps. Such mishaps involve primarily ground and ramp activities and can lead directly to a mishap or injury. Consequently, the present profile and observed relationships only hold for the mishaps considered and cannot be generalized to all MRMs. Further, it can be contended interventions developed for major mishaps that primarily involving maintenance activities such as engine repair are likely not appropriate for ones of lesser severity that involve other activities such as loading ordnance or towing aircraft. **Presently, an in-depth analysis of all MRMs is underway and it is planned to contrast major vs. minor MRMs, MRMs occurring during maintenance, stores, and ramp activities, and MRMs for specific communities.**

Slide 31



HFACS-ME Summary

- ➢HFACS-ME is effective in classifying aviation maintenance causal factors
- ➢ HFACS-ME enables organizations to develop successful accident intervention strategies
- ➢HFACS-ME should be applied to both major and minor accidents to fully analyze maintenance errors

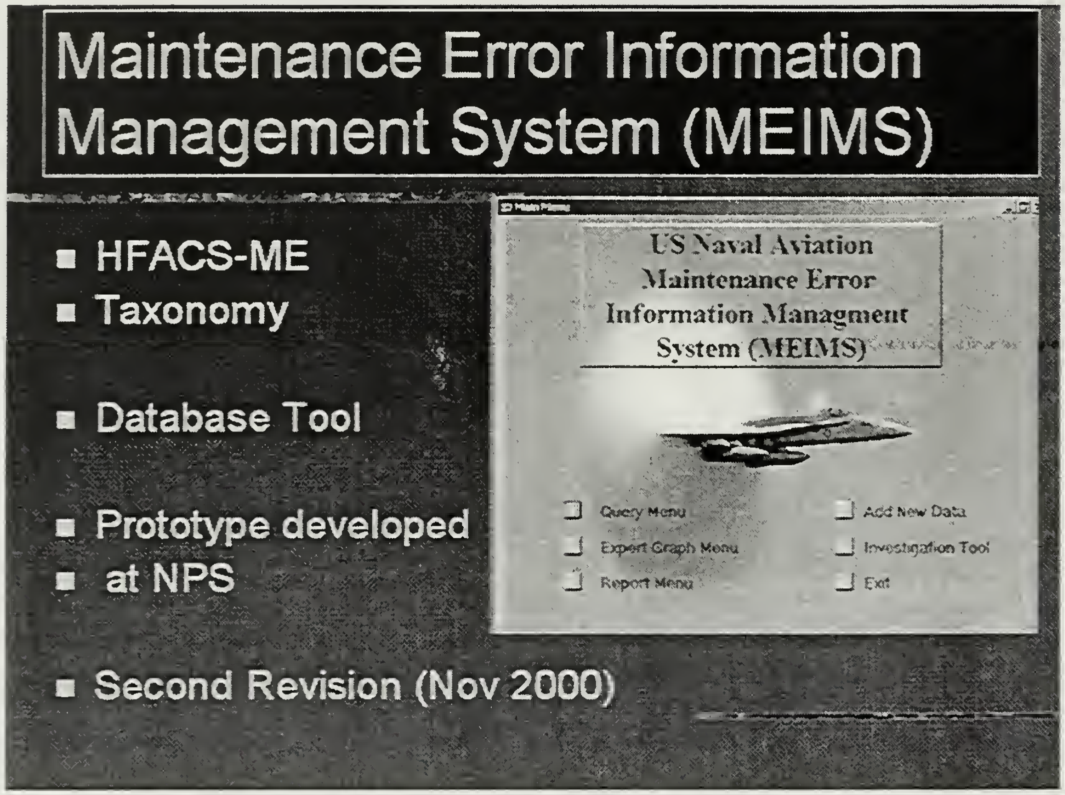
Presentation Summary:

The HFACS-ME model, as you have just seen, has demonstrated effectiveness.

With HFACS-ME, a safety organization can:
- effectively classify (code) maintenance related accident causal factors
- develop specific intervention strategies to mitigate causal factors

NOTE: Because most major mishaps occur during flight operations, it is essential to also evaluate the "minor" mishaps and incidents that occur on the ramp and in the hangar. Such mishaps involve activities that can lead directly to damage to the aircraft or injury to the maintainer.

Slide 32



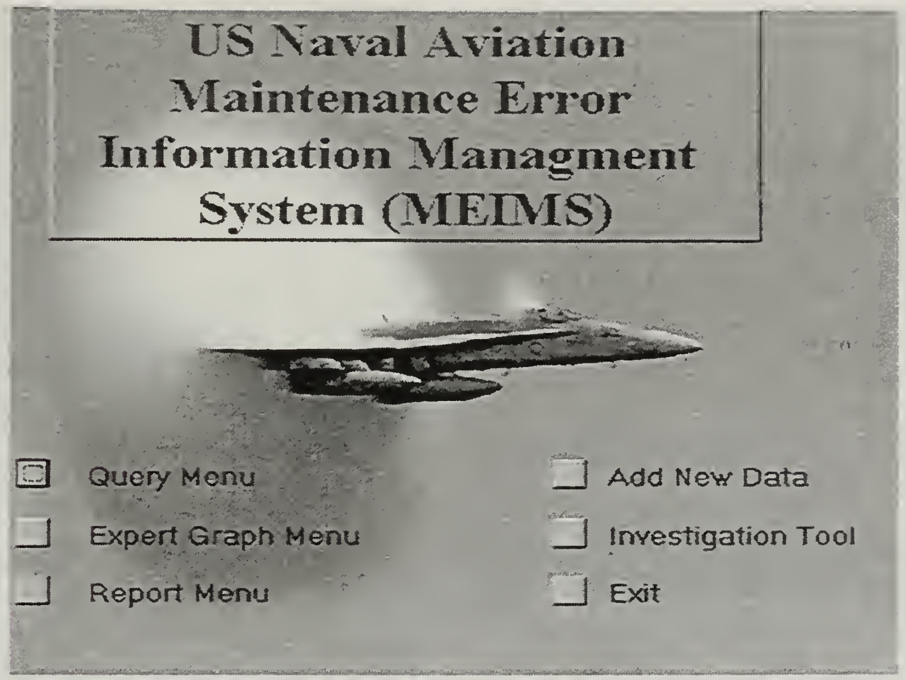
Maintenance Error Information Management System (MEIMS)

- HFACS-ME
- Taxonomy
- Database Tool
- Prototype developed
- at NPS
- Second Revision (Nov 2000)

Now that we have some understanding of the HFACS-ME, lets take a look a the prototype database tool which uses that taxonomy. It is called MEIMS, Maintenance Error Information Management System.

This is an Access 2000 based prototype, developed at NPS, the latest revision just recently completed.

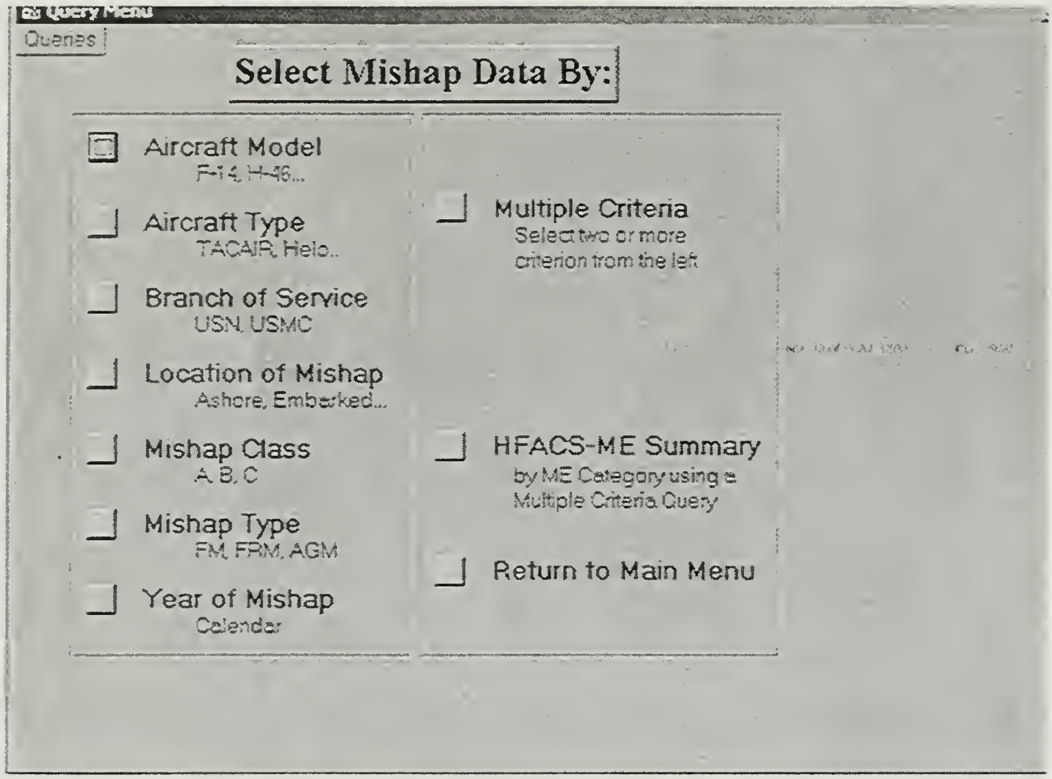
Slide 33


US Naval Aviation Maintenance Error Information Managment System (MEIMS)
Query Menu
Expert Graph Menu
Report Menu
Add New Data
Investigation Tool
Exit

The Main Menu

Notice the five button functionality, plus exit. Placing your pointer over any of the menu selections will give you a brief description of that selection.

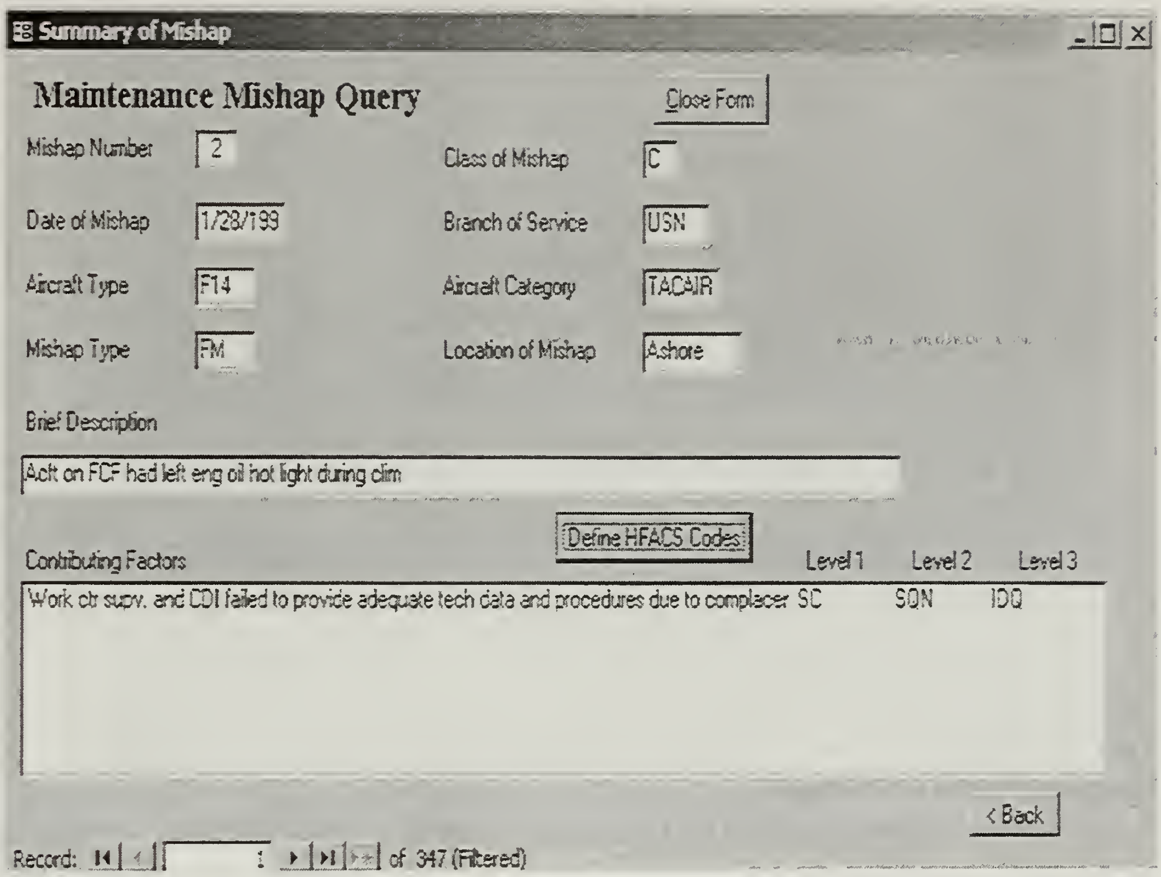
Slide 34



The query menu.

The user may select one or many (using the Multiple Criteria button) choices from the left and get mishap information regarding that particular selection(s).

Slide 35



Maintenance Mishap Query

Mishap Number: 2
Date of Mishap: 1/28/199
Aircraft Type: F14
Mishap Type: FM
Class of Mishap: C
Branch of Service: USN
Aircraft Category: TACAIR
Location of Mishap: Ashore

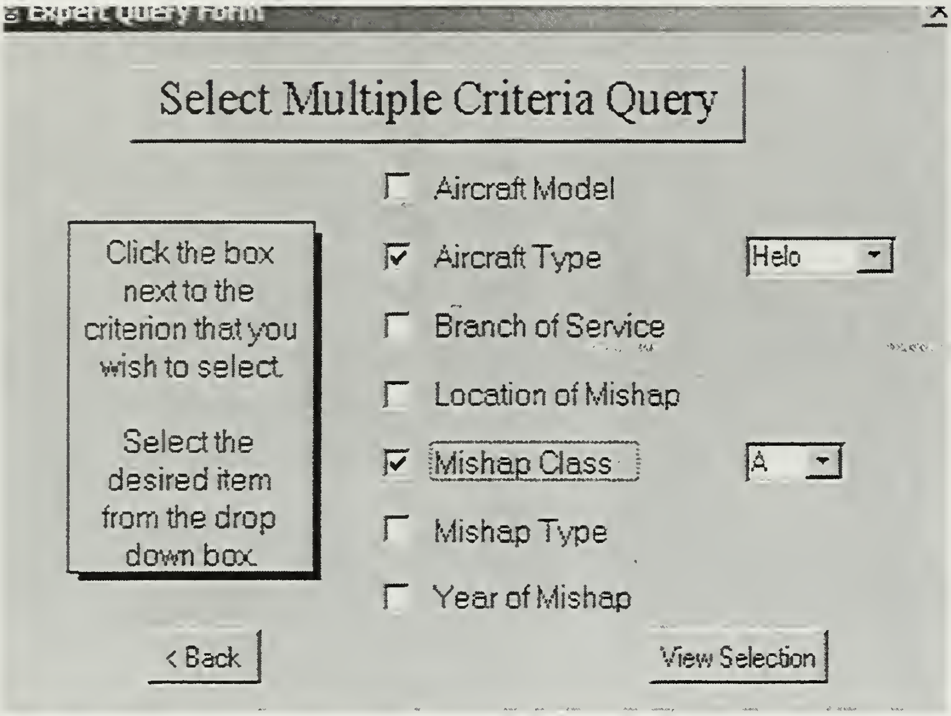
Brief Description: Acft on FCF had left eng oil hot light during clim

Contributing Factors	Level 1	Level 2	Level 3
Work ctr supv. and CDI failed to provide adequate tech data and procedures due to complacer	SC	SQN	IDQ

Record: 1 of 347 (Filtered)

This is the TACAIR selection. Notice that the selected criteria is in blue. There is a brief description, contributing factors and the codes for Levels 1, 2 & 3. Definitions for those codes can be found by clicking on the "Define HFACS Codes" button. Also, at the bottom, the number of mishaps meeting that criteria.

Slide 36



Select Multiple Criteria Query

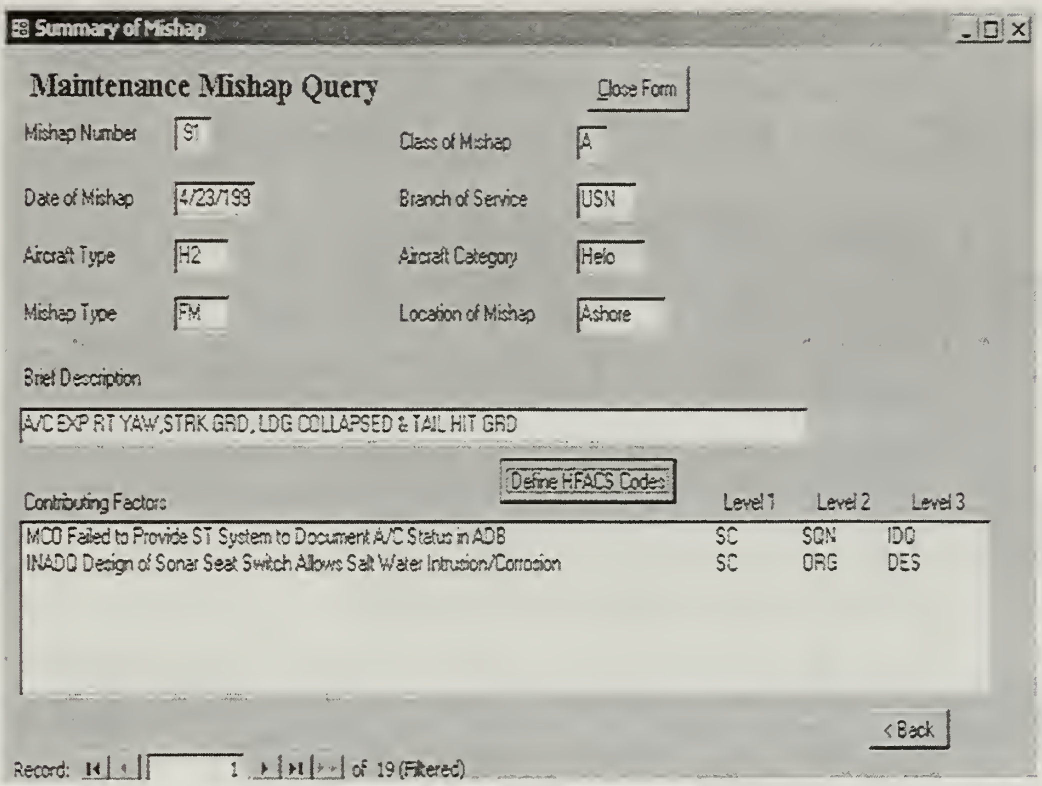
Click the box next to the criterion that you wish to select.

Select the desired item from the drop down box.

☐ Aircraft Model
☑ Aircraft Type: Helo
☐ Branch of Service
☐ Location of Mishap
☑ Mishap Class: A
☐ Mishap Type
☐ Year of Mishap

This is the Multiple Criteria Selection screen. Again, the mishaps meeting the selection criteria are viewed…

Slide 37



Maintenance Mishap Query

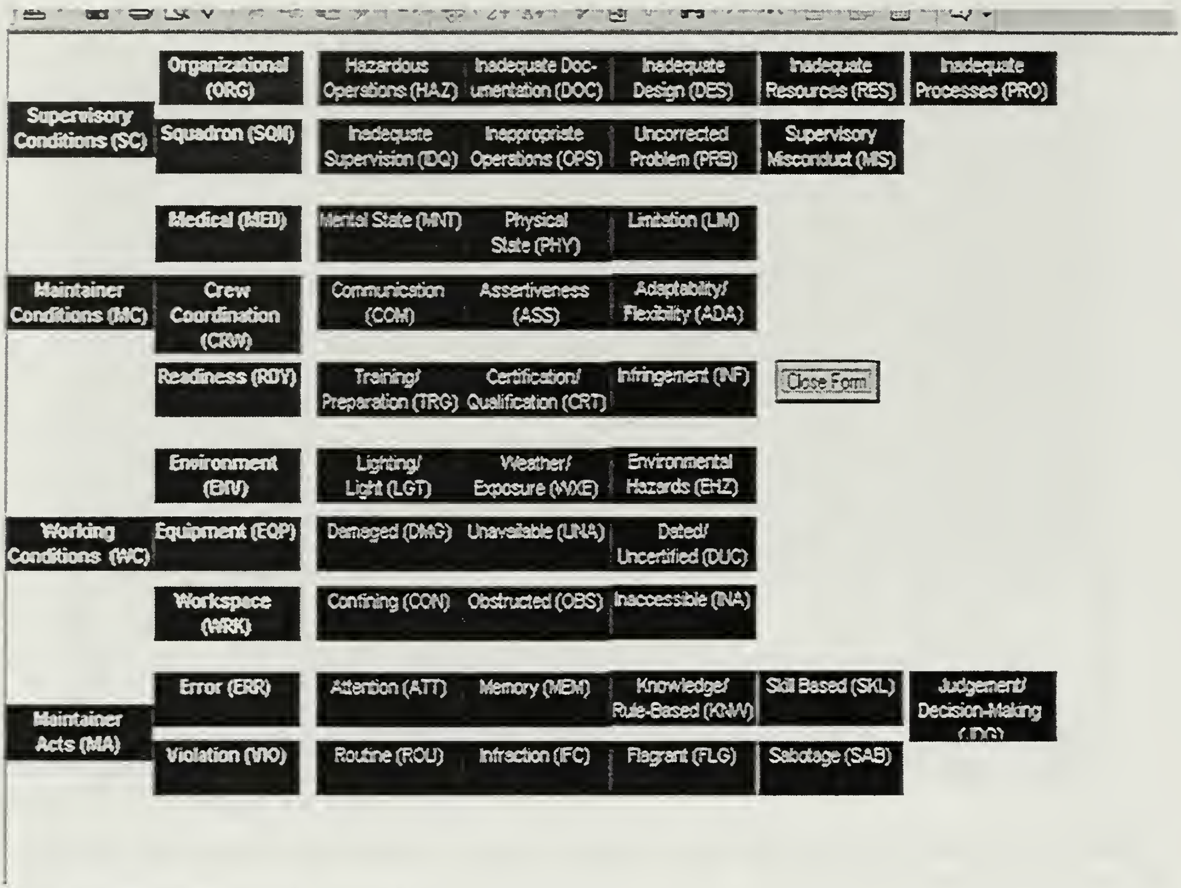
Mishap Number: ST
Class of Mishap: A
Date of Mishap: 4/23/199
Branch of Service: USN
Aircraft Type: H2
Aircraft Category: Helo
Mishap Type: FM
Location of Mishap: Ashore

Brief Description: A/C EXP RT YAW,STRK GRD, LDG COLLAPSED & TAIL HIT GRD

Contributing Factors	Level 1	Level 2	Level 3
MCO Failed to Provide ST System to Document A/C Status in ADB	SC	SQN	IDO
INADQ Design of Sonar Seat Switch Allows Salt Water Intrusion/Corrosion	SC	ORG	DES

...with the selection criteria in blue. Define HFACS Codes allows the user to view the codes for each level...

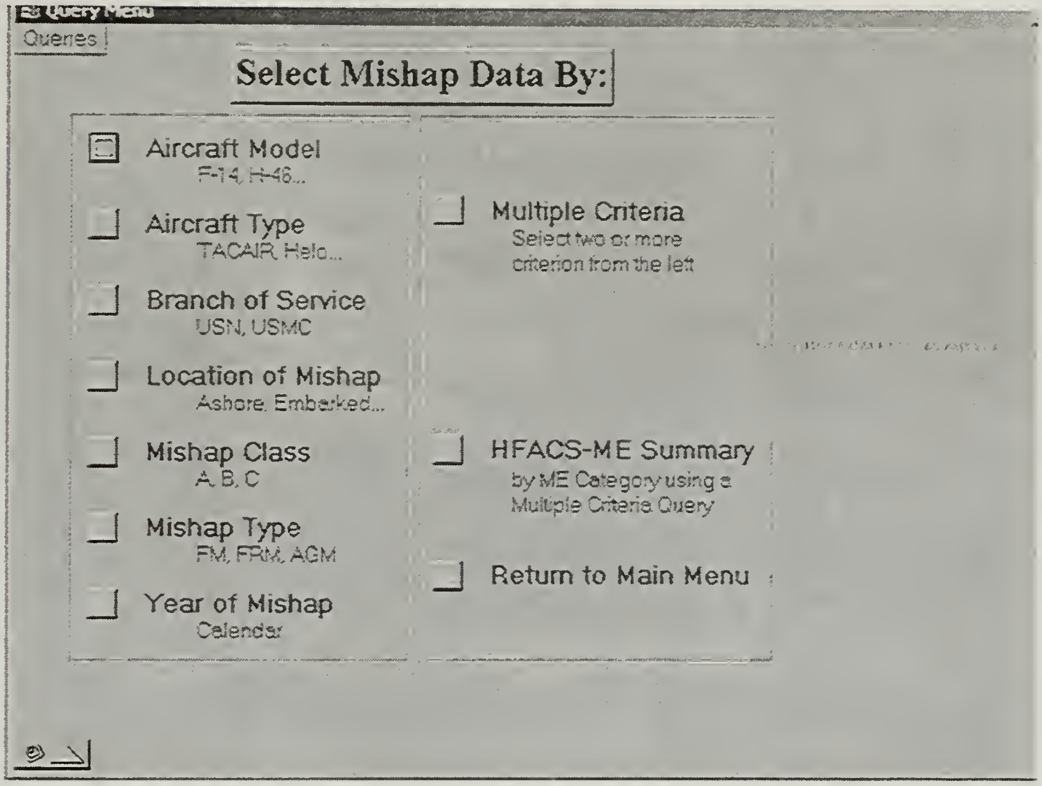
Slide 38



Supervisory Conditions (SC)	Organizational (ORG)	Hazardous Operations (HAZ)	Inadequate Documentation (DOC)	Inadequate Design (DES)	Inadequate Resources (RES)	Inadequate Processes (PRO)
	Squadron (SQN)	Inadequate Supervision (IDQ)	Inappropriate Operations (OPS)	Uncorrected Problem (PRB)	Supervisory Misconduct (MIS)	
Maintainer Conditions (MC)	Medical (MED)	Mental State (MNT)	Physical State (PHY)	Limitation (LIM)		
	Crew Coordination (CRW)	Communication (COM)	Assertiveness (ASS)	Adaptability/ Flexibility (ADA)		
	Readiness (RDY)	Training/ Preparation (TRG)	Certification/ Qualification (CRT)	Infringement (INF)		
Working Conditions (WC)	Environment (ENV)	Lighting/ Light (LGT)	Weather/ Exposure (WXE)	Environmental Hazards (EHZ)		
	Equipment (EQP)	Damaged (DMG)	Unavailable (UNA)	Dated/ Uncertified (DUC)		
	Workspace (WRK)	Confining (CON)	Obstructed (OBS)	Inaccessible (INA)		
Maintainer Acts (MA)	Error (ERR)	Attention (ATT)	Memory (MEM)	Knowledge/ Rule-Based (KNW)	Skill Based (SKL)	Judgement/ Decision-Making (JDG)
	Violation (VIO)	Routine (ROU)	Infraction (IFC)	Flagrant (FLG)	Sabotage (SAB)	

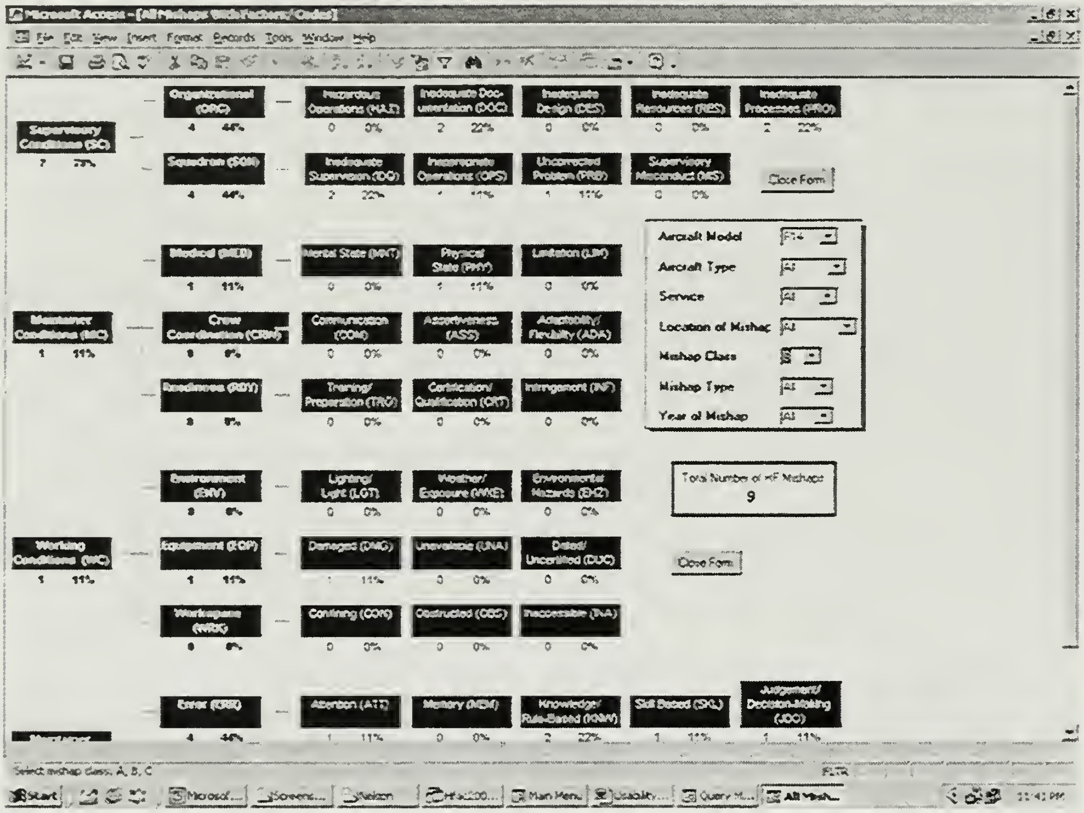
...traveling right to left in Levels 1, 2 & 3

Slide 39



And Selecting HFACS-ME Summary gets the user…

Slide 40


Microsoft Access - [All Mishaps With Factors/Codes]
File Edit View Insert Format Records Tools Window Help
Supervisory Conditions (SC) 7 78%
Organizational (ORG) 4 44%
Hazardous Operations (HAZ) 0 0%
Inadequate Documentation (DOC) 2 22%
Inadequate Design (DES) 0 0%
Inadequate Resources (RES) 0 0%
Inadequate Processes (PRO) 2 22%
Squadron (SQN) 4 44%
Inadequate Supervision (ISO) 2 22%
Inappropriate Operations (OPS) 1 11%
Uncorrected Problem (PRB) 1 11%
Supervisory Misconduct (MIS) 0 0%
Close Form
Medical (MED) 1 11%
Mental State (MNT) 0 0%
Physical State (PHY) 1 11%
Limitation (LIM) 0 0%
Maintainer Conditions (MC) 1 11%
Crew Coordination (CRM) 0 0%
Communication (COM) 0 0%
Assertiveness (ASS) 0 0%
Adaptability/ Flexibility (ADA) 0 0%
Readiness (RDY) 0 0%
Training/ Preparation (TRQ) 0 0%
Certification/ Qualification (CRT) 0 0%
Infringement (INF) 0 0%
Environment (ENV) 0 0%
Lighting/ Light (LGT) 0 0%
Weather/ Exposure (WXE) 0 0%
Environmental Hazards (EHZ) 0 0%
Working Conditions (WC) 1 11%
Equipment (EQP) 1 11%
Damaged (DMG) 1 11%
Unavailable (UNA) 0 0%
Dated/ Uncertified (DUC) 0 0%
Close Form
Workspace (WRK) 0 0%
Confining (CON) 0 0%
Obstructed (OBS) 0 0%
Inaccessible (INA) 0 0%
Error (ERR) 4 44%
Attention (ATT) 1 11%
Memory (MEM) 0 0%
Knowledge/ Rule-Based (KNW) 2 22%
Skill Based (SKL) 1 11%
Judgment/ Decision-Making (JDG) 1 11%
FLTR
Start
Microsof...
Screens...
Nelson
Main Menu
Usability...
Query M...
All Mish...

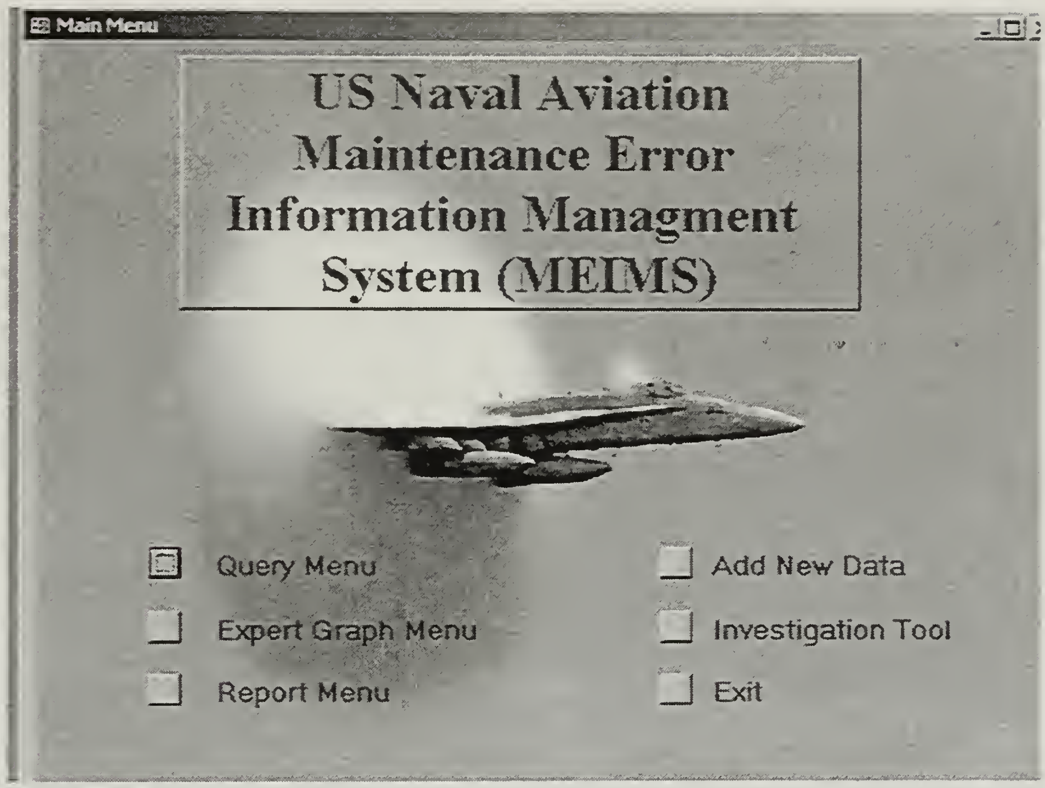
Aircraft Model: F14
Aircraft Type: All
Service: All
Location of Mishap: All
Mishap Class: B
Mishap Type: All
Year of Mishap: All

Total Number of HF Mishaps
9

Select mishap class: A, B, C

...This presentation. Notice that the user can modify the choices directly from this screen (F-14/Class B selected). This summary page is good for pulling out data specific to levels 1-3 or within levels.

Slide 41

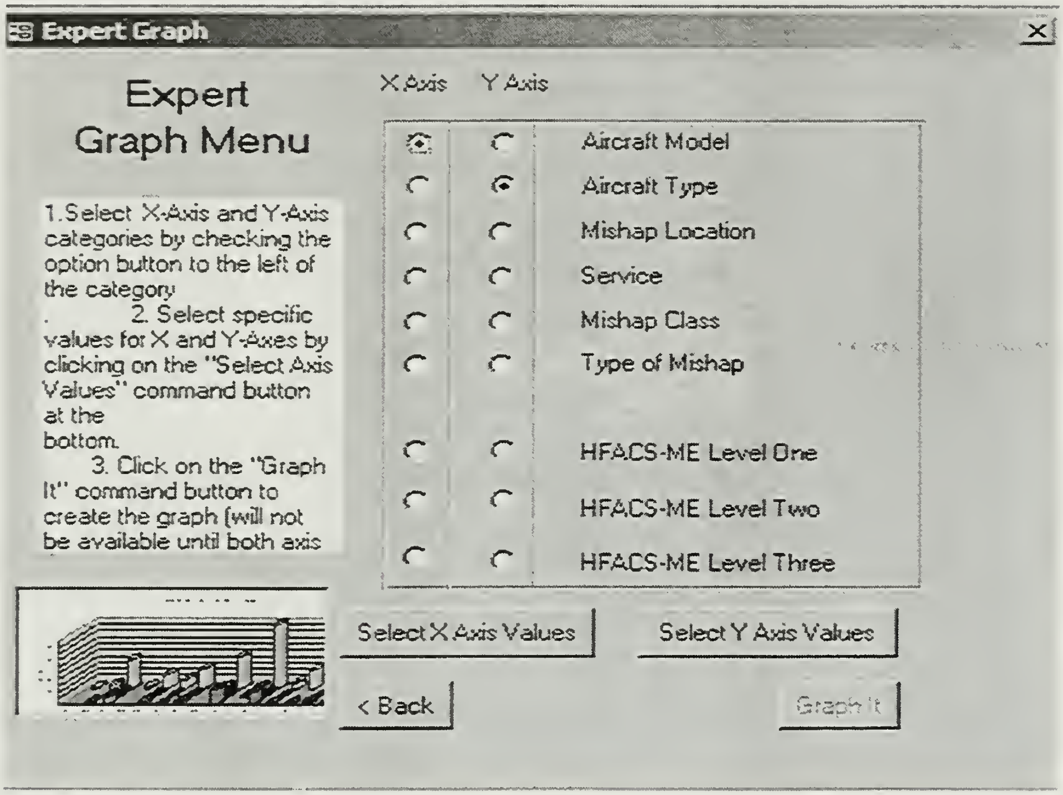


Main Menu

US Naval Aviation Maintenance Error Information Managment System (MEIMS)

Returning to the Main Menu, we will now look at the Graphing Function

Slide 42

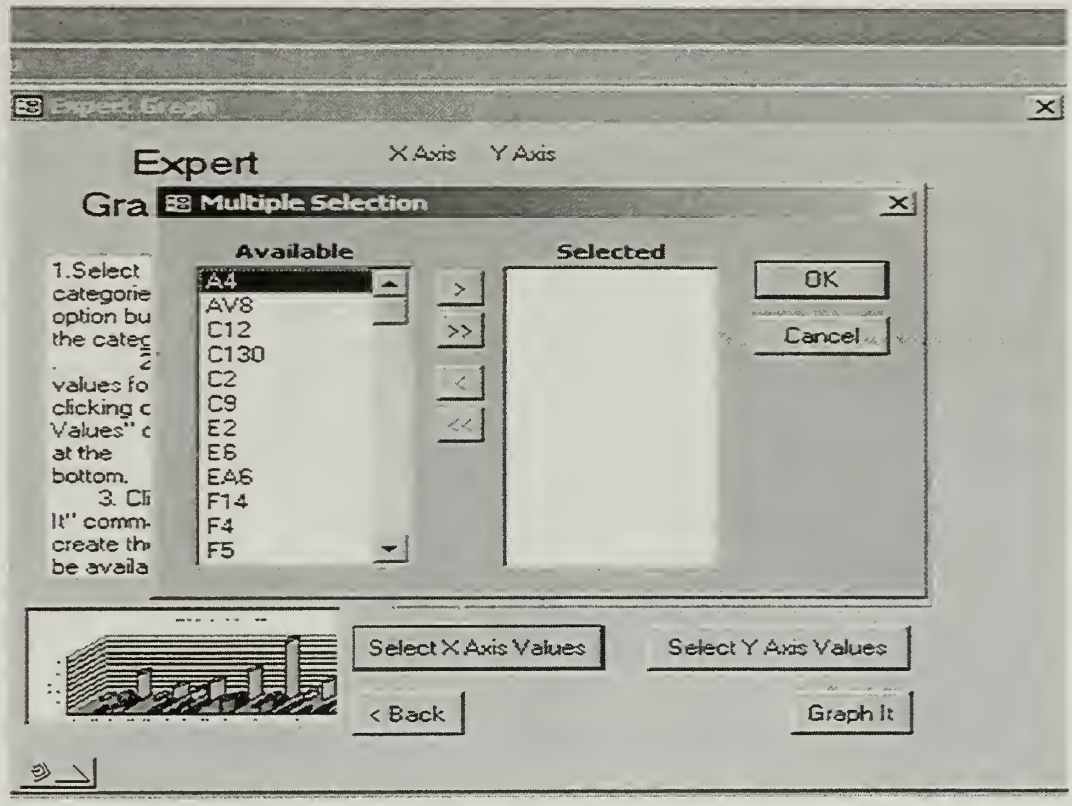


1.Select X-Axis and Y-Axis categories by checking the option button to the left of the category
. 2. Select specific values for X and Y-Axes by clicking on the "Select Axis Values" command button at the bottom.
3. Click on the "Graph It" command button to create the graph (will not be available until both axis

X Axis	Y Axis	
●	○	Aircraft Model
○	●	Aircraft Type
○	○	Mishap Location
○	○	Service
○	○	Mishap Class
○	○	Type of Mishap
○	○	HFACS-ME Level One
○	○	HFACS-ME Level Two
○	○	HFACS-ME Level Three

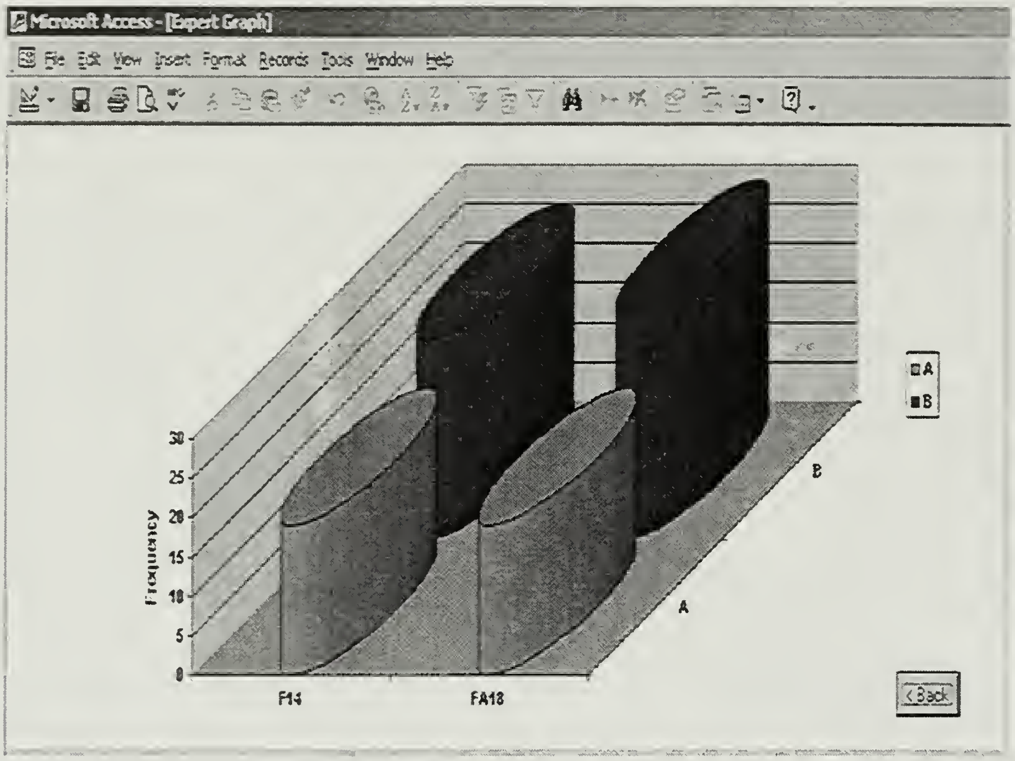
The Graphing Function allows the user to choose which criteria will be on which axis, and then...

Slide 43



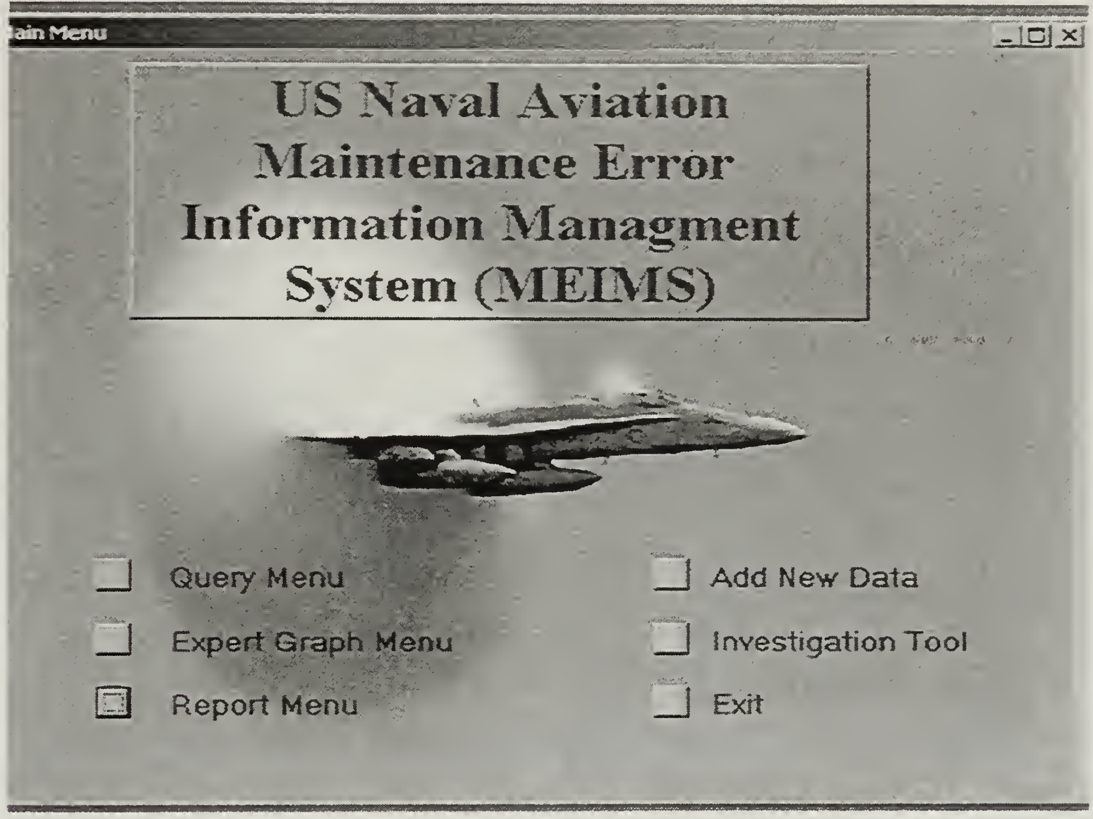
Both the X and Y axis may be further defined to produce....

Slide 44


Microsoft Access - [Expert Graph]
File Edit View Insert Format Records Tools Window Help
Frequency
30
25
20
15
10
5
0
F14
FA18
A
B
A
B
< Back

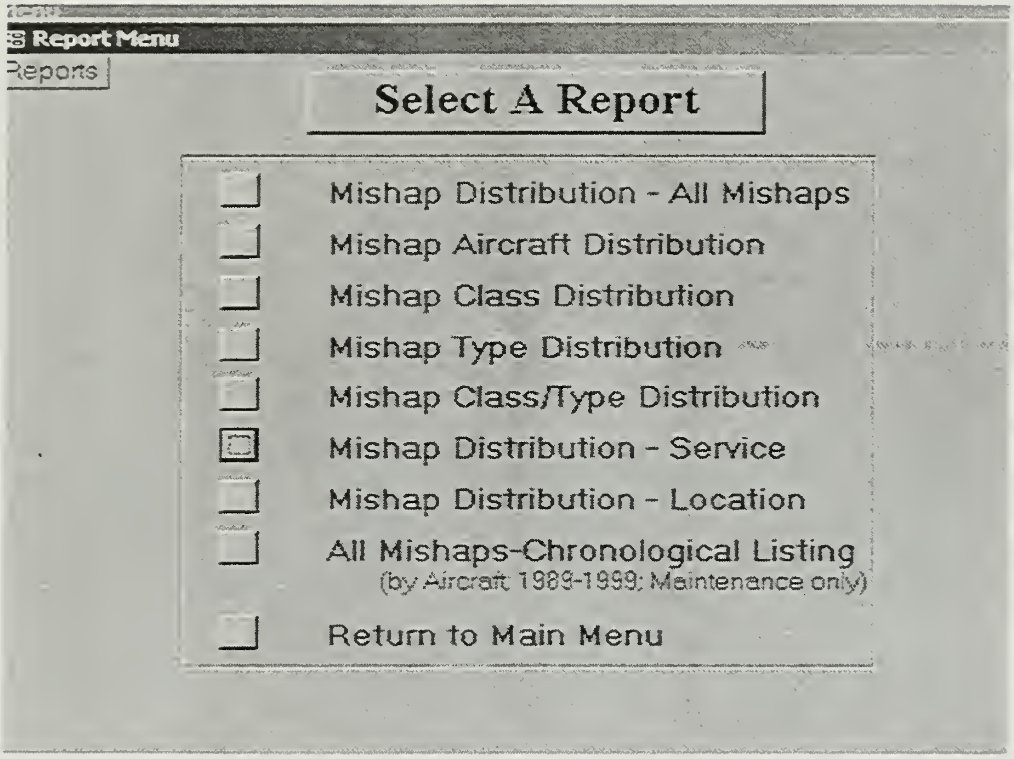
…the selected graph, in this case, F-14 and F18 class A and B mishaps.

Slide 45



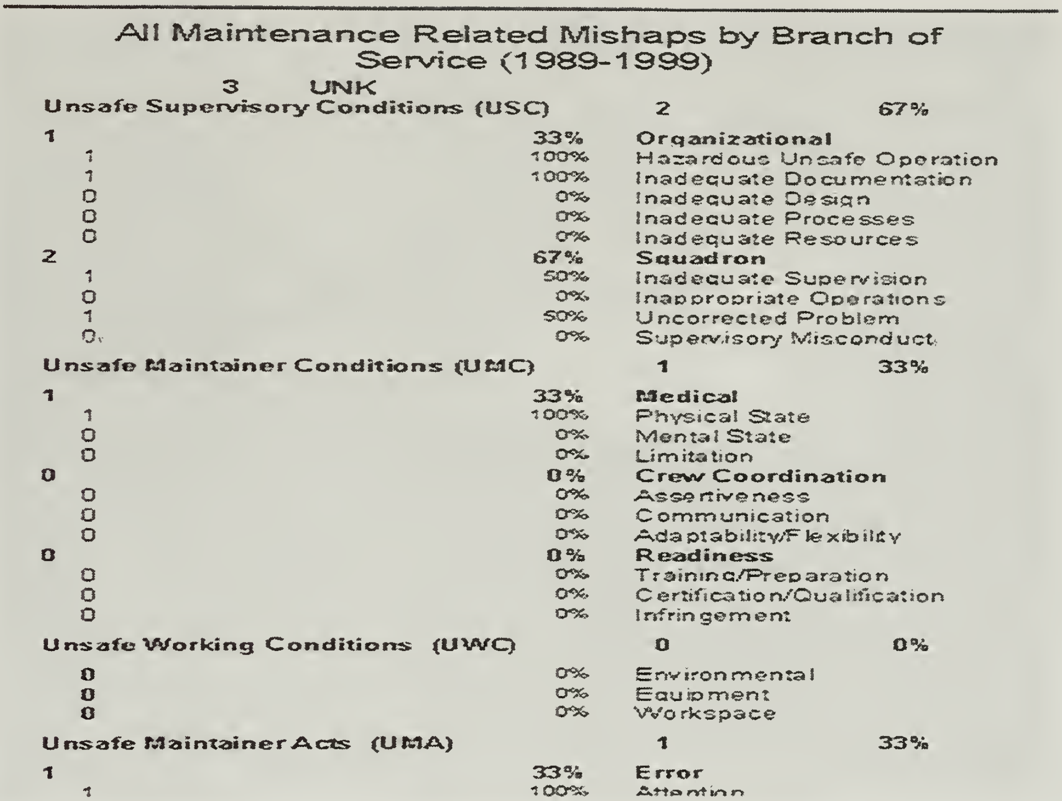
Selecting the REPORT MENU gets…

Slide 46


Report Menu
Reports
Select A Report
☐ Mishap Distribution - All Mishaps
☐ Mishap Aircraft Distribution
☐ Mishap Class Distribution
☐ Mishap Type Distribution
☐ Mishap Class/Type Distribution
☐ Mishap Distribution - Service
☐ Mishap Distribution - Location
☐ All Mishaps-Chronological Listing
(by Aircraft 1989-1999; Maintenance only)
☐ Return to Main Menu

...a choice of multiple reports

Slide 47



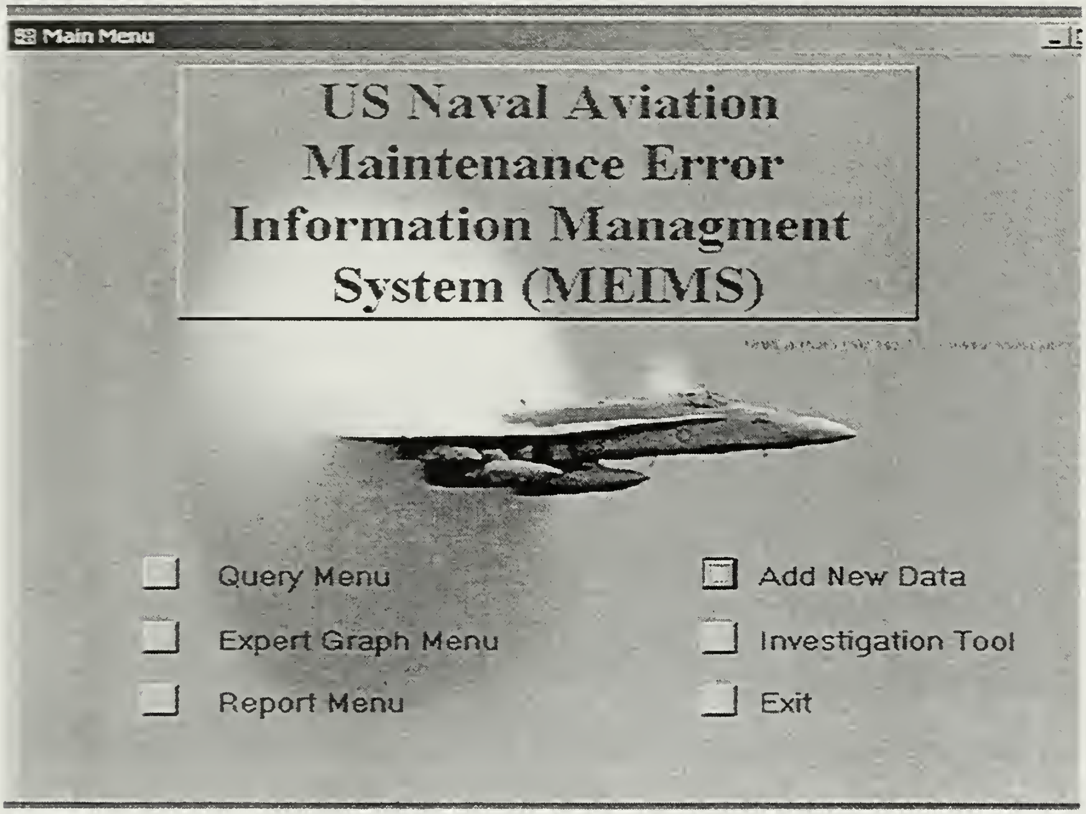
All Maintenance Related Mishaps by Branch of Service (1989-1999)

3 UNK

Unsafe Supervisory Conditions (USC)		**2**	**67%**
1	**33%**	**Organizational**	
1	100%	Hazardous Unsafe Operation	
1	100%	Inadequate Documentation	
0	0%	Inadequate Design	
0	0%	Inadequate Processes	
0	0%	Inadequate Resources	
2	**67%**	**Squadron**	
1	50%	Inadequate Supervision	
0	0%	Inappropriate Operations	
1	50%	Uncorrected Problem	
0	0%	Supervisory Misconduct	
Unsafe Maintainer Conditions (UMC)		**1**	**33%**
1	**33%**	**Medical**	
1	100%	Physical State	
0	0%	Mental State	
0	0%	Limitation	
0	**0%**	**Crew Coordination**	
0	0%	Assertiveness	
0	0%	Communication	
0	0%	Adaptability/Flexibility	
0	**0%**	**Readiness**	
0	0%	Training/Preparation	
0	0%	Certification/Qualification	
0	0%	Infringement	
Unsafe Working Conditions (UWC)		**0**	**0%**
0	0%	Environmental	
0	0%	Equipment	
0	0%	Workspace	
Unsafe Maintainer Acts (UMA)		**1**	**33%**
1	**33%**	**Error**	
1	100%	Attention	

…in this case, the Mishap Distribution by Service.

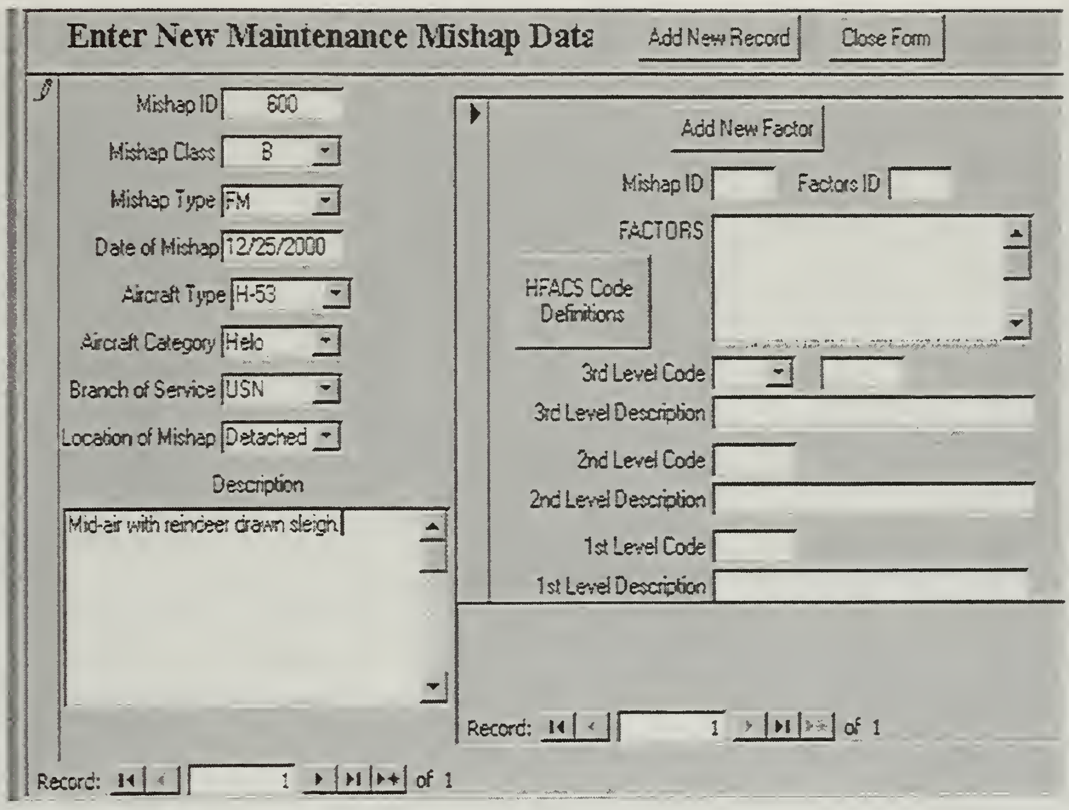
Slide 48



US Naval Aviation Maintenance Error Information Managment System (MEIMS)

The Add New Data button produces…

Slide 49



Enter New Maintenance Mishap Data

Mishap ID: 600

Mishap Class: B

Mishap Type: FM

Date of Mishap: 12/25/2000

Aircraft Type: H-53

Aircraft Category: Helo

Branch of Service: USN

Location of Mishap: Detached

Description: Mid-air with reindeer drawn sleigh.

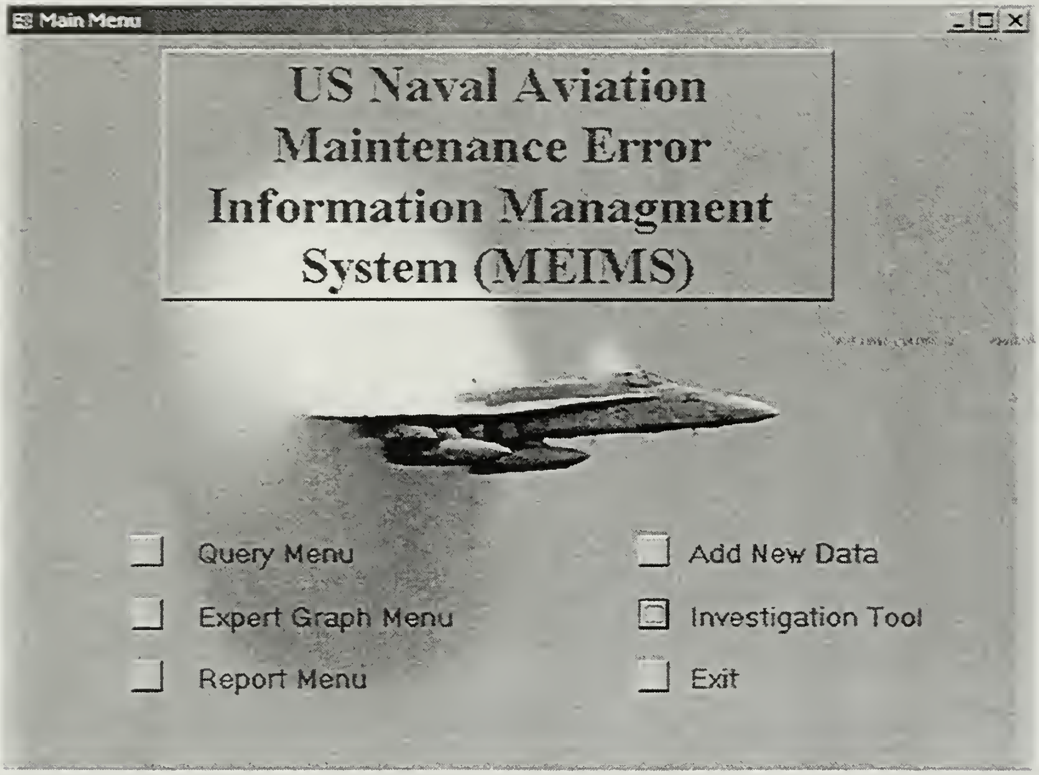
Record: 1 of 1

Record: 1 of 1

A form on which to enter mishap data. In this case, it seems that some of Santa's helpers may have run into some trouble.

Again, on this form, HFACS Code Definitions are available.

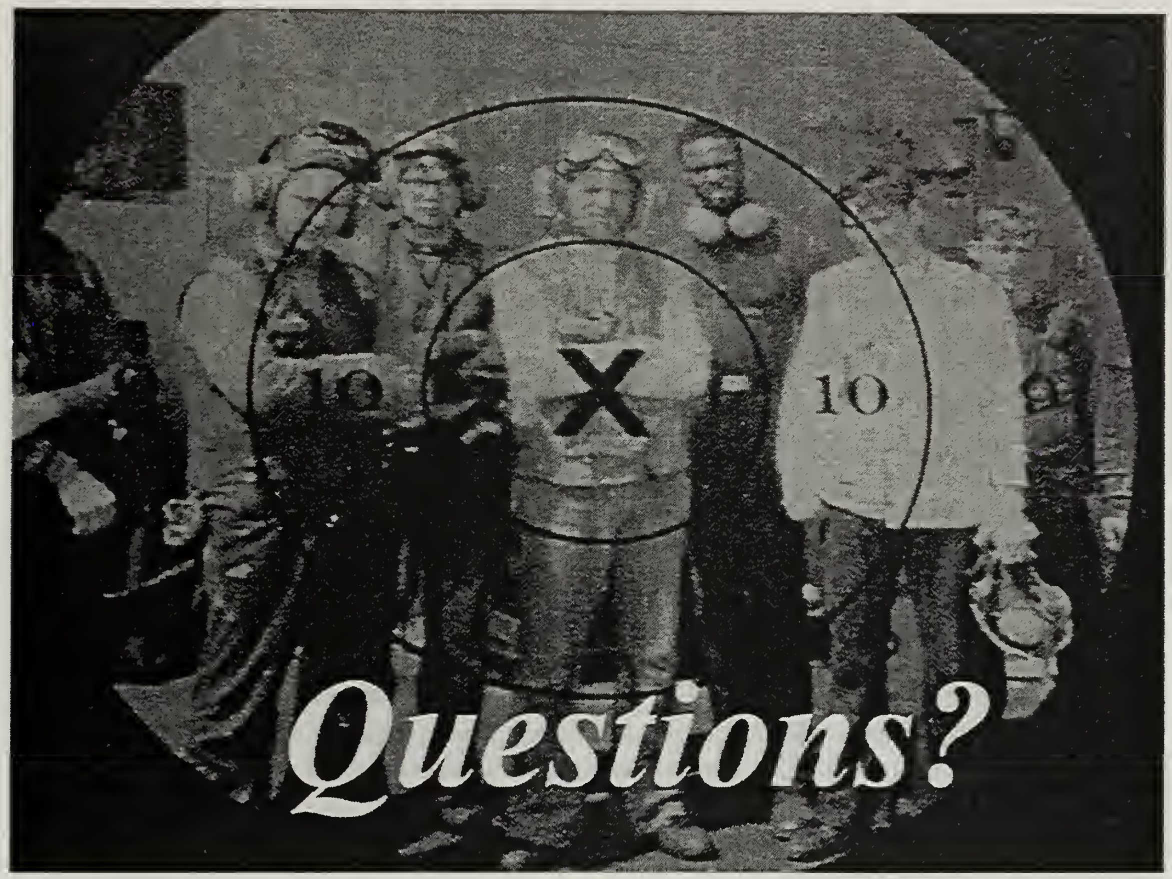
Slide 50



The Investigation Tool is not yet fully functional, but will allow the user to "drill down" into the specifics an individual mishap to better ascertain learning point.

Last, but not least, Exit. This button exits the MEIMS program and Microsoft Access 2000.

Slide 51



This concludes the Tutorial. You now have a better understanding of the individual error categories and their interrelationships in a mishap's chain of events. Additionally, you have seen some of the functionality of the MEIMS tool. If there are no questions, please follow the instructor's directions regarding the usability test.

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APPENDIX C

MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) EVALUATION

Background. Thank you for participating in a usability study (evaluation) of a prototype tool for the Maintenance Error Information Management System (MEIMS). This tool was developed at NPS and has been modified based upon previous usability studies. This study is being conducted by LCDR Mike McCracken, USN as part of a thesis project for his Master of Science program in Information Technology Management. MEIMS was developed to address and identify patterns of human error in Naval Aviation maintenance-related aircraft mishaps. The Human Factors Analysis and Classification System Maintenance Extension (HFACS-ME) taxonomy is the foundation of MEIMS and is an effective method for classifying and analyzing the presence of human error in maintenance operations leading to major mishaps, accidents of lesser severity, incidents and maintenance related personal injury cases. A previous study indicated that prior to using MEIMS a tutorial, explaining the taxonomy and some features, would be beneficial. This study compares two groups of users, one which receives the tutorial and one that does not. Feedback from user groups will be used to further improve MEIMS and the tutorial.

MEIMS captures maintenance error data, facilitates the identification of common maintenance errors and associated trends, and supports understanding of how to identify human errors in the future. The target audience for this information management system tool includes safety personnel (data entry & retrieval by unit safety officers, other safety & training personnel, maintenance officers, maintenance supervisors), mishap investigators-for data retrieval (Aircraft Mishap Board members, squadron safety officers), and analysts (from the Naval Safety Center, the command's safety officer or one from its higher headquarters). This tool allows can directly lead to a decreased mishap rate and overall increased mission readiness due to the training and analysis opportunity it provides.

Usability Study. You will be given a packet of instructions to guide you through MEIMS. You will be asked to make comments on the effectiveness and usability of the prototype system during your testing phase. Additionally, you will be asked to complete an "exit survey" after completion of your testing. Questions will include demographic information, objective questions about MEIMS usability, questions regarding the tutorial and its effectiveness (if applicable), and subjective questions and comments for areas not covered in the objective section. The study should take no more than 15-20 minutes.

Completion of Study. Upon completion of your testing and survey you will be asked to return your packet of instructions to LCDR McCracken. Thank you again for your participation.

Mike McCracken

Instructions for Maintenance Error Information Management System (MEIMS) Tool Evaluation

Start-up

1. Go to a computer lab with OFFICE 2000 loaded. Log on into the NPGS domain. Open Microsoft ACCESS 2000, then using the zip disk provided, open the file Hfac2000.

Question 1: Did you have any problems accessing the program? Y / N (circle one) If so, please describe:

Main Menu

2. You will now have the Main Menu displayed with the world famous Supersonic Hornet photo in the background.

3. Note the six categories next to the command buttons on the bottom right portion of the screen. The system has "focus" on "Query Menu". Note the information on this button in the bottom left gray buffer above the Windows Start button. Place the mouse pointer over the Query Menu box (don't click, if you do, select <Back> on subsequent page) and note information that appears in the Text Box (both of these sources of information will be available throughout MEIMS).

4. Select <Tab> and view the same information for the remaining four command buttons (note, if you select <Exit> you will have to re-enter the system (see step 1 above).

Question 2: Is the terminology clear enough to understand what each of the four command buttons does? If not, what could be changed to make it clearer?

5. Select (click or tab to & enter) <Query Menu>

Query Menu

6. Note there are two sections on the Query Menu. The left half of the screen has seven categories to help you define how you would like to view the mishap data. The right half of the screen has four command buttons.

7. Select <Aircraft Model>

8. Another form appears: "Query by Aircraft Type". Select your type aircraft, then select <View Selection>. "Summary of Mishap" Form appears. Note, your aircraft selection has a blue background. Review the "Brief Description" of the mishap and the "Contributing Factors." View

*Question 3: What aircraft did you select?*__________

*How many separate mishaps of that aircraft type are in the database?*______________

View one of the mishaps.
*What are the level 3 codes & what do they mean?*_______________________________

*How did you find that info?*____

When you are through viewing the data, select <Close Form>
Select another aircraft type, and view some of the mishaps (optional).
When complete select <Back> on Query by Aircraft Model Form

9. Select another category (your option) & view the data.

Question 4: Which (if any) of the seven categories do you find useful?

Which (if any) of the seven categories do you not find useful?

10. Select <Multiple Criteria>. Create your own query using two or more criteria.

Question 5: What Criteria did you choose?

How many mishaps for your selection were in the database? ________

Did you find this function useful? Why or why not?

11. Return to Query Menu. Select <HFACS-ME Summary>.

*Question 6: How many total mishaps are in the database?*____________

*How many mishaps have a level one category of Worker Conditions?*____________

*How many mishaps have a level two category of Medical?*____________

Further define the system by your aircraft model (or select another type).

*Question 7: What aircraft did you select?*__________

*How many separate mishaps of that type aircraft are in the database?*______________

Conduct further queries as desired. When complete, return to Query Menu & return to Main Menu.

11. Select <Report Menu>. Review the six command buttons and their functions.

12. Select <Mishap Distribution - Location>. Review the report data.Find your type aircraft (or review another) in the report. <Close> the report & return to the Report Menu.

*Question 8: How many Detached mishaps are in the database?*____________

13. Select <All Mishaps-Chronological Listing>. Review data. <Close> the report when complete & return to Report Menu. Return to Main Menu.

14. Select <Expert Graph Menu>. Follow directions. Create one graph with aircraft model (yours and 1 or 2 others) on the X-Axis and HFACS-ME Level One (all four codes) on the Y-Axis.

*Question 9: What aircraft did you select?*_______________________

Did you notice a difference in the level one codes between the aircraft (if so, what)?

Return to <Expert Graph Menu>. Try more graphs as desired. When complete, return to Main Menu.

15. Select <Add New Data>. Enter two mishaps to the database:

Question 10: What are the Mishap Numbers for the data you are entering?

___________ ___________

Check to see if your entries were added to the database by Looking at the end of the Chronological Listing on the Report Menu (look for your Mishap Numbers).

Question 11: Did you see your data in the Chronological Listing? _______________

16. Return to Main Menu & Select Investigation tool. This selection is not yet fully functional. It will be used to "drill down" a specific mishap or types of mishap to determine if like factors occur. It will provide enhanced analysis and training benefit. You may choose multiple criteria, just as in query, to limit narrow your focus (optional).

17. Return to Main Menu & Exit the Program.

18. Please fill out the Exit Survey Questionnaire.

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APPENDIX D

MAINTENANCE ERROR INFORMATION MANAGEMENT SYSTEM (MEIMS) EXIT SURVEY

User's Impression of the Maintenance Error Information Management System (MEIMS) Prototype Tool

Purpose: This survey evaluates a user's overall satisfaction of the Maintenance Error Information Management System (MEIMS) prototype tool. It consists of four parts.

Part I: *Demographic Information.* Part I provides the user's aviation background, computer experience, and availability of software and hardware systems used in the Navy and Marine Corps.

Part II: *User Satisfaction with the MEIMS Prototype Tool.* Part II deals directly with user feedback as they use the prototype tool.

Part III: *User Overall Satisfaction with the MEIMS Prototype Tool.* Part III allows users to give general feedback about the prototype tool.

Part IV: (if applicable) *User Satisfaction with the Tutorial.* Part IV allows user to provide feedback about the Tutorial

Part I. Demographic Information

Follow the instructions after each numbered question or statement.

1. I am attached to a command that **primarily performs maintenance** (military and/or civilian) at the:

(Select one from the list and check the box)

☐ Squadron Level
☐ Intermediate Level (AIMD)
☐ Depot Level (NADEP)
☐ Command does not perform aircraft maintenance
☐ Other (describe if other) ________________________________

2. **How long** have you been using a computer?

(Select one from the list and check the box)

☐ Less than one month
☐ One month to less than one year
☐ One year to less than two years
☐ Two years or more

3. What **software** do you normally use?
   (Check all boxes that apply)

- ☐ Microsoft Office (Word, PowerPoint, Excel, Access)

What version?
   (Check all boxes that apply)
   - ☐ 97
   - ☐ 2000
   - ☐ not sure of version
   - ☐ other (describe if other)________________________

- ☐ Lotus Smart Suite (Word Pro, Lotus 123...)

What version?
   (Check all boxes that apply)
   - ☐ 97
   - ☐ 9.5
   - ☐ not sure of version
   - ☐ other (describe if other)________________________

- ☐ Corel Word Perfect Office (Word Perfect, Quattro Pro...)

What version?
   (Check all boxes that apply)

   - ☐ Corel Office 7
   - ☐ 2000
   - ☐ not sure of version
   - ☐ other (describe if other)________________________

- ☐ Other (describe if other) ______________________________________

4. What **software application categories** are you familiar with?
   (Check all boxes that apply)

- ☐ Word Processing (MS Word, Word Perfect, Word Pro...)
- ☐ Spreadsheet (Excel, Lotus 123, Quattro Pro...)
- ☐ Presentations (PowerPoint, Harvard Graphics...)
- ☐ Graphic Software (Corel Draw, Adobe Photoshop...)
- ☐ E-Mail (Outlook, Eudora, AOL...)
- ☐ Database (Access, DBase...)

5. What computer **operating systems** do you use?
(Check all boxes that apply)

- ☐ Windows (3.1, 95, 98, 2000)
- ☐ Windows NT
- ☐ Macintosh
- ☐ UNIX
- ☐ Linux
- ☐ Other (describe if other) ________________________________

Part II. User Satisfaction with the Four Sections of the MEIMS Prototype Tool
Select the category that best matches your impression of each of the below categories (and check the box).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I feel the information on the MEIMS tool was in a **logical form**					
I found the MEIMS tool **easy to navigate**					
My tour of the MEIMS tool was **very interesting**					
The information presented on the MEIMS tool is **relevant to maintenance operations**					
The **concept** of the MEIMS tool is a good one.					

Part III. User Overall Satisfaction with the MEIMS Prototype Tool
Please make any comments on the MEIMS Prototype Tool not reflected in your comments in sections 1 and 2.

The most positive aspects of the MEIMS prototype tool were:

The most negative aspects of the MEIMS prototype tool were:

I would make these changes (if any) to the MEIMS prototype tool:

If you received the Tutorial, please continue on to Part IV. If you did not receive the Tutorial, you are complete. Thank you! Your participation is greatly appreciated!

Part IV. User Satisfaction with the Tutorial

Select the category that best matches your impression of each of the below categories (and check the box).

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
I feel the information in the Tutorial was **beneficial**					
The Tutorial made the evaluation **easier to complete**					
The Tutorial was **interesting**					
The information presented in the Tutorial is **relevant to the MEIMS tool**					
The **concept** of a tutorial is a good one.					

Comments

Please make any additional comments on the Tutorial.

The most positive aspects of the Tutorial were:

The most negative aspects of the Tutorial were:

I would make these changes (if any) to the Tutorial.

Thank you! Your participation is greatly appreciated!

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